Glaustas Horticulture

P. Muthukumar
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GLAUSTAS HORTICULTURE

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PREFACE

"Glaustas Horticulture" it provides an over view of the concise and clearly expressed principles and practices in horticultural crops. In the present edition an effort has been made to present science-led developments in Indian or world horticulture, the ongoing research efforts at national level and some new technologies like genome sequencing in horticultural crops and smart breeding tools. The aim has been to present a complete and modern view of the horticultural science. Some special chapters have also been added dealing with basic concepts not usually covered in other horticulture examination books.

Key features

The book is aimed for contains 9 chapters of whole horticulture for various examinations (ARS/NET Preliminary, ICAR-SRF, IARI Ph.D, SAU Ph.D, State level H.O and ICAR-JRF) and other competitive examinations. The first 2 Chapters brings the idea about role of horticulture in Indian economy and the basic concepts to bring together the diverse information related to the horticultural crops. The Chapters 3-9 which deal with Pomology, Olericulture, Commercial floriculture, Plantation crops, Spices and Condiments, Medicinal and aromatic plants and Post harvest technology in horticultural crops.

I lay claim to originality. Some of the subjects have been attempted in various different ways, before. I take the responsibility for any lapses in content, format and approach of the contents and also for any other errors, either scientific or linguistic and will look forward to receiving reader's corrections or suggestions for improvement of book. The research information, research reports and concepts are collected from top ranked journals with good impact factor,

and authorized article printouts. Inevitably we may omitted some of the topics that will be included in future editions. I hope that this book will be useful for U.G, P.G, Ph.D horticulture students, teachers and horticulture people across the country. The main motto of the book to bring next generation young people, especially horticultural background B.Sc, M.Sc. Ph.D (all degree in Horticulture), I called it as triple plus (+++) peoples.

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I. Statistics of Horticultural Crops

Area, Production and Productivity of Horticultural Crops in India during 2013-14

Particulars	Area (M ha)	Area share (%)	Production (Mt)	Production share (%)	Productivity (Mt/ha)	India Position	World scenario
ruits ncluding uts)	7.21	29.80	88.97	32.07	12.30	2nd (13.6%)	1st China (20.9%)
egetables	9.39	38.81	162.89	58.73	17.30	2nd (14%)	1st China (49.5%)
owers oose)	0.25	1.03	1.75	0.82	6.90	-	-
ices	3.16	13.06	5.90	2.12	1.90	-	-
matic dicinal os	0.49	2.02	0.89	0.32	1.8	-	-
ntation os	3.67	16.30	16.30	5.87	4.40	-	-
al	24.19	-	277.35	-	11.5	-	-

Leading Horticultural Crops in India during 2013-14

rticulars	Area	Production	Productivity
its	Mango > Citrus > Banana	Banana > Mango > Citrus	Papaya > Banana > Apple
etables	Potato > Tomato > Onion	Potato > Onion > Tomato	Tapioca > Cabbage > Potato
tation s	Coconut > Cashew > Arecanut	Coconut > Cashew > Arecanut	Coconut > Cashewnut
s	Chilli > Garlic > Turmeric	Chilli > Garlic > Turmeric	Garlic > Turmeric

3. State-Wise leading Area, Production and Productivity of in Horticultural crops during 2013-14

Crops	Area	Production	Productivity
Fruits	Maharashtra > Andhra Pradesh > Gujarat	Maharashtra > Andhra Pradesh > Gujarat	Madhya Pradesh
Vegetables	West Bengal > UP> Bihar	West Bengal> UP > Bihar	Tamil Nadu
Plantation crops	Kerala	Kerala	Kerala
Spices	Rajasthan	Andhra Pradesh	Arunachal Pradesh
Cut flowers	West Bengal	West Bengal>Karnataka > Odisha	Bihar
Loose flowers	Tamil Nadu	Tamil Nadu>Karnataka > Madhya Pradesh	-

4. Area, Production and Productivity of major Fruit Crops in India during 2013-14

Fruits	Area (M ha)	Area Share (%)	Production (Mt)	Production Share (%)	Producti-vity (Mt/ha)	India Position in world fruit produc-tion	World Scenario in fruit production
Banana	0.803	11.50	29.72	33.40	37.0	-	1st India (27.8%)
Mango	2.516	34.90	18.43	20.71	7.3	-	1st India (45.1%)
Citrus	1.078	14.93	11.14	12.52	10.3	-	-
Papaya	0.113	1.80	5.63	6.33	42.3	-	1st India (43.7%)
Guava	0.268	3.71	3.66	4.12	13.7	-	1st India (45.1%)
Apple	0.119	1.64	2.58	2.90	21.8	5th	1st China
Pineapple	0.313	1.50	2.49	2.0	15.8	6th	1st Philippines
Sapota	0.177	2.45	1.74	1.96	9.9	-	-
Grapes	0.110	1.60	1.73	2.90	15.8	9th	1st China
Pomeg-ranate	0.131	1.81	1.34	1.51	10.3	-	--
Litchi	0.084	1.16	5.85	6.57	7.0	-	-
Others	1.484	20.56	9.87	11.09	6.7	-	-
Total Fruits	**7.216**	**29.82**	**88.97**	**32.07**	**12.30**	-	-

(Source: NHB Database, 2013-14)

Mha: Million hactares; Mt: Million tonnes; t/ha: tonnes/ha

5. State-Wise leading Area, Production and Productivity of Fruit Crops in India during 2013-14:

Fruits	Area	Production	Productivity
Banana	Tamil Nadu	Tamil Nadu	Madhya Pradesh
Mango	Maharashtra	Uttar Pradesh	Uttar Pradesh
Citrus	Andhra Pradesh	Andhra Pradesh	Karnataka
Papaya	Gujarat	Andhra Pradesh	Tamil Nadu
Guava	Uttar Pradesh	Madhya Pradesh	Madhya Pradesh
Apple	Jammu & Kashmir	Jammu & Kashmir	Jammu &Kashmir
Pineapple	Assam	West Bengal	West Bengal
Sapota	Maharashtra	Maharashtra	Tamil Nadu
Grapes	Maharashtra	Maharashtra	Maharashtra
Pomegranate	Maharashtra	Maharashtra	Andhra Pradesh
Litchi	Bihar	Bihar	Punjab

6. Area, Production and Productivity of major Vegetable Crops in India during 2013-14:

Vegetables	Area (M ha)	Area share (%)	Production (Mt)	Production Share (%)	Productivity (Mt/ha)	India position in world production	World Scenario in production	World Scenario in productivity (1st)
Potato	1.973	20.99	41.555	25.50	21.7	2nd India (11.4%)	1st China	USA
Tomato	0.882	9.38	18.736	11.50	21.2	2nd India (11.5%)	1st China	USA
Onion	1.204	12.81	19.402	11.91	16.1	2nd India (22.6%)	1st China	USA
Brinjal	0.711	7.56	13.558	8.32	19.1	2nd India (27.2%)	1st China	Spain
Tapioca	0.228	2.42	8.139	4.99	35.7	1st India	-	Japan
Cabbage	0.400	4.25	9.039	5.54	22.6	2nd India (12.8%)	1st China	Japan
Cauliflower	0.434	4.61	8.573	5.26	19.8	2nd India (37.5%)	1st China	Germany
Okra	0.533	5.67	6.346	3.89	11.9	1st India (72.9%)	-	Ghana
Peas	0.434	4.61	3.869	2.37	8.9	-	-	-
Sweet Potato	0.106	1.12	1.088	0.66	10.3	-	-	-
Others	2.492	26.52	32.591	20.00	13.1	-	-	-
Total	9.396	38.82	162.897	58.73	17.3	-	-	-

7. State-wise leading Area, Production and Productivity of Vegetable Crops during 2013-14

Vegetables	Area	Production	Productivity
Potato	Uttar Pradesh	Uttar Pradesh	Madhya Pradesh
Tomato	Andhra Pradesh	Andhra Pradesh	Madhya Pradesh
Onion	Maharashtra	Maharashtra	Gujarat
Brinjal	West Bengal	West Bengal	Karnataka
Tapioca	Tamil Nadu	Tamil Nadu	Tamil Nadu
Cabbage	West Bengal	West Bengal	Madhya Pradesh
Cauliflower	West Bengal	West Bengal	West Bengal
Okra	West Bengal	West Bengal	Chhatishgarh
Peas	Uttar Pradesh	Uttar Pradesh	Jammu& Kashmir
Sweet Potato	Odisha	Odisha	Madhya Pradesh

8. Area, Production and Productivity of Major Spices in India during 2013-14:

Spices	Area (M ha)	Production (Mt)	Production share (%)	Productivity (Mt/ha)
Chillies	0.775	1.492	22.87	1.9
Garlic	0.231	1.252	19.77	5.4
Turmeric	0.233	1.190	18.56	5.1
Ginger	0.133	0.655	13.12	4.9
Cumin	0.859	0.514	9.01	0.6
Coriander	0.447	0.314	3.86	0.7
Tamarind	0.059		5.87	3.2
Fenugreek	0.066	0.118	2.21	1.4
Fennel	0.054	0.105	1.97	1.3
Pepper	0.124	0.052	0.97	0.4
Cardamom	0.093	0.015	0.29	0.2
Ajwan	0.027	0.022	0.41	0.7
Nutmeg	0.019	0.011	0.21	0.7
Tejpat/Cinnamon	0.003	0.005	0.09	1.8
Clove	0.002	0.001	0.02	0.5
Other spices	0.044	0.034	0.76	0.8
Total	**3.163**	**5.908**	**2.23**	**1.9**

9. **State-wise leading Area, Production and Productivity Major Spices Crops in India during 2013-14**

Area (M ha)	Production (Mt)	Productivity (Mt/ha)
Rajasthan > Madhya Pradesh > Gujarat	Gujarat > Andhra Pradesh > Rajasthan	Arunachala Pradesh > Haryana> Andhra Pradesh

10. **Area, Production and Productivity of Major Plantation Crops in India during 2013-14**

Plantation crops	Area (M ha)	Production (Mt)	Production share (%)	Productivity (Mt/ha)
Coconut	2.140	14.910	91.46	7.0
Cashewnut	1.011	0.753	4.61	0.7
Arecanut	0.452	0.622	3.81	1.4
Cocoa	0.071	0.015	0.09	0.2
Total	**3.675**	**16.301**	-	**4.4**

11. **State-wise leading Area, Production of Plantation Crops in India during 2013-14**

Plantation crops	Area	Production
Coconut	Kerala > Karnataka > TN	Kerala > Karnataka > TN
Cashewnut	Andhra Pradesh > Maharashtra > Odisha	Maharashtra > Andhra Pradesh > Odisha
Arecanut	Karnataka > Kerala > Assam	Karnataka > Kerala > Assam
Cocoa	TN > Andhra Pradesh > Kerala	Kerala > Andhra Pradesh > Karnataka

12. **Export of Horticultural produce in India during 2013-14**

Export commodity	Export share (%)
Fresh onions	22.1
Other Fresh vegetables	16
Fresh mangoes	2
Fresh grapes	11.6
Other Fresh fruits	7.0
Walnuts	2.3
Dried and preserved vegetables	5.2
Mango pulp	5.4
Other processed fruits and vegetables	15.8
Floriculture	3.2
Fruit and vegetable seeds	2.9
Cucumber and gherkin (preserved)	6.6

13. **Status of horticultural crops:**

- ★ Horticulture plays an important role in India's economy accounting for about 30.7% of India's agricultural GDP from 13.7% of cropped area
- ★ Horticulture sector provides employment for 20% of the labour force
- ★ Horticulture crops occupy only 14.0% of the total cropped area
- ★ Highest number of released varieties in horticultural crops: Vegetables (57%), plantation and spices (22%), fruits (22%)

A. Fruits:

- ★ India is the 2nd largest producer of fruits after China
- ★ India accounts 13.59% of global total fruit production
- ★ In India, Fruits occupy 29.82% of area and 32.07% of total horticultural area and production respectively, with average productivity of 12.3 Mt/ha.
- ★ States leading fruit area: Maharashtra
- ★ States leading fruit production: Maharashtra (15%)
- ★ States leading fruit productivity: Madhya Pradesh (28 MT/ha)
- ★ Among fruit crops, production share of Major fruit crops: Banana (33.4%), Mango (20.7%) Citrus (12.5%)

★ Among fruit crops, production share of states in Major fruit crops: MH (15%), Andhra Pradesh (12%), Gujarat (9%)

★ Among fruit crops, area share of states in Major fruit crops: MH (22%), Andhra Pradesh (9%), Gujarat (5%)

★ Among fruit crops Mango occupies maximum area: 2.5 Mha (34.90 % of the total area under the fruits)

★ Among fruit crops Banana occupies maximum production: 29.72 Mt (33 % of the total production under the fruits)

★ India ranks 1st in mango, banana, papaya and guava production in the world

★ Uttar Pradesh (UP) is the leading producer of mango

★ Andhra Pradesh (AP) is the leading producer of citrus and papaya

★ West Bengal (WB) is the leading producer of pine apple

★ Jammu and Kashmir (JK) is the leading producer of apple and nut crops

★ Tamil Nadu (TN) leads in area, production of banana

★ Madhya Pradesh is the leading guava producing state in India

★ Maharashtra is leading in production of sapota in India

★ Leading citrus, papaya producing state in India: Andhra Pradesh

★ Leading grapes producer in India: Maharashtra

★ Leading Pomegranate (70%) producing state in India: Maharashtra

★ Bihar is the leading producer of litchi

★ Post harvest handling losses in fruits: 20-40%

★ Hub of mango manufacturing unit in India: Krishnagiri District of Tamil Nadu

★ Year round pine apple producing state: Tamil Nadu

★ Year round guava producing state: Andhra Pradesh

★ Year round lime/lemon producing state: Punjab

★ Year round pomegranate producing state: Tamil Nadu, Maharashtra

★ Year round sapota producing state: Maharashtra

B. Vegetables:

★ India is the 2nd largest producer of vegetables after China

★ Annual per capita availability of vegetables: 120 kg/person

★ Vegetables occupy 38.9% of area and 61% of total horticultural area and production respectively

★ Vegetables shares 2% of the total cropped area

★ India shares about 14.04 % of the total vegetable production of the world

★ States leading vegetable area: West Bengal

★ States leading vegetable production: West Bengal

★ States leading vegetable productivity: Tamil Nadu (19.8 MT/ha)

★ Among vegetable crops, production share of Major vegetable crops: Potato (22.25%), Onion (11.9%), Tomato (11.5%)

★ Among vegetable crops, production share of major states in vegetable crops: West Bengal (14.1%), Uttar Pradesh (11.4%), Bihar (9.3%)

★ Among vegetable crops, area share of major states in vegetable crops: West Bengal (14.7%), Uttar Pradesh (9.1%), Bihar (8.6%)

★ India is the second largest producer of tomato, brinjal and cauliflower

★ India leads in production of bhendi and garden pea

★ Among vegetable crops potato occupies maximum area: 1.97 Mha (20.9% of the total area under the vegetables)

★ Among vegetable crops potato occupies maximum production: 41.55 Mt (25.50% of the total production under the vegetables)

★ Total F_1 hybrids area share: Cabbage (90%), Cucumber (80%), Water melon (70%), Brinjal (57%), Tomato (51%)

★ TN leads in area, production and productivity of tapioca

★ Maharashtra (MH) is the leading producer of onion about 30%

★ West Bengal (WB) is the leading producer of brinjal, okra, cauliflower, cabbage

★ Uttar Pradesh (UP) is the leading producer of potato (33%), garden pea (46%)

★ Andhra Pradesh (AP) is the leading producer of tomato

★ Odisha is the leading producer of sweet potato

★ Tamil Nadu is the leading producer of tapioca (61%)

★ Most of the vegetables if properly grown can give yield which is 5-10 times than any cereal crop

★ Fresh onion contributes maximum % (25%) among horticultural crops export

★ Post harvest handling losses in vegetables: 20-30%

★ India's major export of spice products are in the raw and bulk form: 80%

★ Year round cabbage, cauliflower producing states: Karnataka, Tamil Nadu

★ Year round okra fruit producing states: Karnataka, West Bengal

★ Year round garden pea producing state: Karnataka

★ Year round garden pea producing states: Tamil Nadu, Maharashtra

★ Year round potato producing state: Tamil Nadu

C. FLORICUTURE:

★ The area under floriculture production in India was 0.25 million hectares with a production of 2.29 Million tonnes of loose flowers and 0.47 thousand tonnes cut flowers (2013-14)

★ In India 98.5% of flowers grown under open cultivation. Only 1.5% flowers were grown under green house.

★ In India about 90% area is under traditional flower that is mostly loose flowers

★ In India more than 70% of the floricultural exports from dry flowers

★ India's total export of floriculture was Rs. 479.42 crores (2015-16)

★ There are more than 300 export-oriented units in India. More than 50% of the floriculture units located in Karnataka, Andhra Pradesh and Tamil Nadu

★ Leading global floricultural export market: Netherlands (58%), Columbia (14%),

★ India's contribution in global floricultural export market (0.6%)

★ India is the largest exporter of Jasmine oil in the world. It accounts about 40% of total world exports in Jasmine oil

★ Leading countries for global floriculture export market: Netherland (58%), Columbia (14%)

★ Germany, France and UK: Top consumers of floricultural products in the world

★ Top rank cut flowers: rose, tulip, chrysanthemum

★ Top rank pot plants: Kalanchoe, Hedera

★ India is the 2nd largest flower grower after China

★ Rose contribute 70% of the total cut flower industry trade

★ India is a flower power country

★ Protected cultivation of flowers occupy 5% of the total flower crop area

★ Leading cut flower producing states: West Bengal (27%), Karnataka (13%), Odisha (11%)

★ Leading loose flower producing states: Tamil Nadu (19%), Karnataka (12%), Madhya Pradesh (11%)

★ Highest loose flower productivity: Bihar (17.05 t/ha)

★ Flowers export share of India: US (18.65), Netherlands (14.5), Germany (13%)

★ Export potential: Dry flower export (71%), fresh cut flowers (18%), ornamental plants (9%) and fresh bulbs and foliage plants (1%)

★ Demand of dry flowers is increasing at 8-10% per annuum

★ Dried flowers and their value added craft items contribute 2/3rd of our total floricultural export

★ Leading dry flower exporter in India: Ramesh Flowers Pvt Ltd. (40%)

★ Floriculture agri-export zones in india: 6

★ Leading flower seed production in India: Punjab and Haryana

II. Horticultural Institutes

♣ Central Institute of Horticulture (CIH), Mediziphema, Nagaland

♣ Institute of Horticulture Technology (IHT), New Delhi

♣ Indian Institute of Horticultural Research (IIHR), Hessaraghatta, Bangalore, Karnataka

♣ National Bureau of Plant Genetic Resource Center (NBPGR), New Delhi

♣ National Horticultural Board (NHB) established in 1984, HQ in Gurgaon, Haryana

♣ National Horticultural Mission (NHM): 2005-06

♣ The Ministry of Agriculture has announced 2012 as the "Year of Horticulture"

Pomological Research Institutes:

♣ Central Institute of Subtropical Horticulture (CISTH), Lucknow, Uttar Pradesh

♣ Central Institute of Temperate Horticulture (CITH), Srinagar, Jammu and Kashmir

♣ Central Arid Zone Research Institute (CAZRI), Jodhpur, Rajasthan

♣ Central Institute of Arid Horticulture (CIAH), Bikaner, Rajasthan

♣ National Research Centre for Banana (NRCB), Trichy, Tamil Nadu

♣ National Research Centre for Citrus (NRCC), Nagpur, Maharashtra

♣ National Research Centre for Grapes (NRCG), Pune, Maharashtra

♣ National Research Centre for Pomegranate (NRCP), Solapur, Maharashtra

♣ National Research Centre for Litchi (NRCL), Muzaffarpur, Bihar

♣ National Research Centre for Makhana (NRCM), Darbhanga, Bihar

Olericulture research institutes:

♣ Indian Institute of Vegetable Research (IIVR), Varanasi, Uttar Pradesh

♣ Central Tuber Crops Research Institute (CTCRI), Sreekariyam Thiruvananthapuram Kerala

♣ Central Potato Research Institute (CPRI), Shimla, Himachal Pradesh

♣ National Horticultural Research and Development Foundation (NHRDF), Nas Maharashtra

- Directorate on Onion and Garlic Research (DOGR), Nasik, Maharashtra
- Directorate of Mushroom Research (DMR), Solan, Himachal Pradesh

Floricultural research institutes:

- Directorate of Floricultural Research (DFR), Pune, Maharashtra
- National Research Centre for Orchids (NRCO), Pakyong, Gangtok, Sikkim
- National Botanical Research Institute (NBRI), Lucknow, Uttar Pradesh
- Institute of Himalayan Bio-resource Technology (IHBT), Palampur, Himachal Pradesh

Plantation crops research institutes

- Central Plantation Crops Research Intitue (CPCRI), Kasargod, Kerala
- Central Coffee Research Institute (CCRI), Chikmagalur, Karnataka
- Directorate of Cashew Research (DCR), Puttur, Karnataka
- Directorate of Oil Palm Research (DOPR), Pedavegi, Eluru, Andhra Pradesh
- United Planters' Association of Southern India (UPASI), Glenview, Conoor, Nilgiris District, Tamil Nadu
- UPASI Tea Research Foundation (UPASI TRF), Valparai, Coimbatore District, Tamil Nadu
- Tea Research Institute (TRI), Nirar Dam, Valparai, Tamil Nadu
- Central Arecanut and Cocoa Marketing and Processing Co-operative Limited (CAMPCO), Mangalore, Karnataka
- Directorate of Cashew and Coconut Development (DCCD), Cochin, Kerala
- Directorate of Arecanut and Spices Development (DASD), Calicut, Kerala

Boards:

- Coconut Development Board (CDB), Cochin, Kerala
- Tea Board of India, Kolkata, West Bengal
- Coffee Board of India, Chikmagalur, Karnataka
- Cashew Export Promotion Council of India (CEPC), Ernakulam, Kerala

Spices research institutes:

- Indian Institute of Spices Research (IISR) (Previously, NRC on Spices), Calicut, Kerala.
- National Research Centre for Seed Spices (NRCSS), Tabiji, Ajmer, Rajasthan
- Indian Cardamom Research Institute (ICRI), Myladumpara, Idukki, Kerala

Boards:

- Spices Board established in 1987, Cochin, Kerala (Ministry of commerce and industry)

Medicinal and aromatic plants research centres:

- Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow, Uttar Pradesh
- Directorate of Medicinal and Aromatic Plants Research (DMAP), Anand, Gujarat (Previously known as National Research Center for Medicinal and Aromatic Plants (NRCMAP))
- National Medicinal Plants Board (NMPB), New Delhi

Post harvest research centres in India:

- ★ Indian Institute of Crop Processing Technology (IICPT), Thanjavur, Tamil Nadu
- ★ Fruit Preservation and Canning Institute (FPCI), Lucknow, Uttar Pradesh
- ★ Central Post Harvest Engineering and Technology (CIPHET), Ludhiana, Punjab
- ★ Central Food Technological Research Institute (CFTRI), Mysore, Karnataka
- ★ Central Food Laboratory (CFL), Kolkata, West Bengal
- ★ Food Research and Standardization Laboratory (FRSL), Ghaziabad, Uttar Pradesh
- ★ Defence Food Research Laboratory (DFRL), Mysore, Karnataka
- ★ National Institute of Food Technology Entrepreneurship and Management (NIFTEM), Kundli, Haryana
- ★ National Agricultural Cooperative Marketing Fedration of India Ltd. (NAFED), New Delhi
- ★ Regional Research Laboratory (RRL.) Jammu
- ★ Bhabha Atomic Research Centre (BARC), Trombay, Bombay
- ★ Public Health Laboratory (PHL), Pune, Maharashtra
- ★ Agricultural and Processed Food Products Export Development Authority (APEDA), New Delhi

Horticultural Societies:

- ★ Royal Horticultural Society (RHS) was founded in London, England: 1804
- ★ Agri-horticultural society of India (AHSI): 1820, Kolkata, India
- ★ American Society of Horticultural Science (ASHS): 1903, Duke Street Alexandria, United States of America
- ★ Horticultural Society of India (HSI) : 1942, Pusa, New Delhi
- ★ International Society of Horticultural Science (ISHS), Leuvien, Belgium: 1959
- ★ Indian Society of Ornamental Horticulture (ISOH): 1990
- ★ Indian Society of Vegetable Science (ISVS): 1993

International Horticultural Research centers:

- ★ Global Horticulture Initiative (GHI), Rome, Italy
- ★ Horticulture Research International (HRI), Wellesbourne, United Kingdom: 2004
- ★ International Network for the Improvement of Banana and Plantain (INIBAP), Montpellier , France
- ★ Biodiversity International, Rome, Italy
- ★ World Vegetable Center (WVC), Taiwan (Previously known as Asian Vegetable Research and Development Center, AVRDC)
- ★ International Potato Centre (CIP), Peru
- ★ International Registration Authority for Rose (IRAS), USA
- ★ International Registration Authority for Bougainvillea (IRAB), New Delhi
- ★ International Flower Market (IFM), Alsmeer, Netherland
- ★ International Flower Auction Centre (IFAC), Bangalore, Karnataka
- ★ International Cut Flower Grower Association: USA
- ★ International American Spice Trade Association, Washington, D.C., USA
- ★ Royal New Zealand Institute of Horticulture (RNZIH), Canterbury, New Zealand

AICRP Headquarters:

- ♣ AICRP on Tropical Fruits, Bangalore, Karnataka
- ♣ AICRP on Sub-Tropical Fruits, Lucknow, Uttar Pradesh
- ♣ AICRP on Arid Zone Fruits, Bikaner, Rajasthan
- ♣ AICRP on Vegetables crops, Varanasi, Uttar Pradesh
- ♣ AICRP on Tuber Crops, Thiruvananthapuram, Kerala
- ♣ AICRP on Potato, Shimla, Himachal Pradesh
- ♣ AICRP Mushroom, Solan, Himachal Pradesh
- ♣ AICRP on Floriculture, Pune, Maharashtra
- ♣ AICRP on Cashew, Puttur, Karnataka
- ♣ AICRP on Palms, Kasaragod, Kerala
- ♣ AICRP on Spices, Calicut, Kerala
- ♣ AICRP on Medicinal and Aromatic Plants including Betel vine, Anand, Gujarat

Chapter - 2
General Horticulture

1. **Seedlessness in Horticultural Crops**
2. **Biodiversity in Horticultural Crops**
3. **Protected Cultivation of Horticultural Crops**
4. **Hydroponics in Horticultural Crops**
5. **Mineral Nutrition in Horticultural Crops**
6. **Organic Farming in India**
7. **Role of Plant Growth Regulators in Horticultural Crops**
8. **Major Vitamins Present in Horticultural Crops**
9. **Biotechnology of Horticultural Crops**

- The term horticulture is derived from the Latin *hortus* (garden) and *cultura* (cultivation), which means garden cultivation
- The term horticulture is recent origin appeared in 17th century
- Father of horticulture: Thomas Andrew Knight, John Lindley, Liberty Hyde Bailey
- Father of vegetables: L.H. Bailey, USA
- Father of modern orchidlogy: John Lindley
- 1st book in horticulture: Fruit growing in India- W.B. Hayes (1945)
- 1st horticulture book published in india related to Litchi crop
- India is the 2nd largest producer of fruits in the world
- Golden revolution: Fruit production
- Horticulture crops fetch 20-30 times more foreign exchange/unit are than creates due to higher yields of price

1. Seedlessness in Horticultural Crops

★ Development of fruits without fertilization or pollination

★ Parthenocarpy term coined by Null, 1902.

Parthanogenesis

Type of parthenocarpy:

1. **Natural parthenocarpy/obligatory parthenocarpy/autonomic parthenocarpy:**
   - Development of seedless fruits due to genetic sterility (requires vegetative method of propagation) *e.g.* Banana, Japanese persimmon, Pineapple
2. **Facultative parthenocarpy:**
   - Production of seeded or seedless fruits due to environmental stimulation
     e.g. Grapes, tomato mutants, citrus cultivars, cucumber, watermelon
   - Parthenocarpy in tomato: controlled by single recessive gene (*pat-2*)
3. **Vegetative parthenocarpy:**
   - Natural parthenocarpy arises without any external stimulation *e.g.* Banana, pineapple, apple
4. **Stimulative parthenocarpy:**
   - Development of parthenocarpy fruits requires on external stimulation (*i.e.* pollination)
     e.g. Grape var. Black Corianth, watermelon
5. **Stenospermocarpy:**
   - Term coined by Stout, 1936.
   - Fruits are developed from normal pollination and fertilization but the abortion of embryo leads to seedlessness *e.g.* Grape cv. Thompson Seedless (All commercial cultivars), watermelon
   - Seedlessness in grapes extensively studied by Dr. Olmo, 1934.
   - Presence of stenospermocarpy in grapes cultivars: e.g. Grape cv. Sultania and Black Monukka

★ Spontaneous mutant of seedless fruits very common in apple and citrus

Seedlessness in citrus

- Absence of pollination leads to parthenocarpy in citrus spp

★ **Absolutely seedless cultivars in citrus:**

- Mandarin seedless cultivar: Clemenules
- Satsuma mandarin (*Citrus unshiu*)
- Sweet orange cv. Washington Navel Orange
- Tahiti lime (due to triploid)
- Oroblanco (*Citrus grandis* × *Citrus paradisi*)

★ **Artificial parthenocarpy:**

Crops	Growth regulator
Tomato	IAA, GA3
Loquat	GA3
Orange, Lemon, Grapes	IAA
Brinjal	2,4-D, IAA

2. Biodiversity in Horticultural Crops

- Biodiversity: is the sum of total diversity in the biosphere around the planet
- *'Sui generis'* is a Latin word which means 'a system of its own'
- A right conferred for plant variety protection system is PBR (Plant Breeders Right)
- New plant varieties are registered under PPV&FR Act for Plant Breeders Rights
- Indian IPR protection of varieties: *Sui generis*
- Indian *sui generis* system: Protection of plant varieties are provided by PPV&FR
  - Protection of Plant Varieties and Farmer's rights Act, 2001
  - Protection of Plant Varieties and Farmer's rights rules notified, 2003
  - PPV&FR come into force 2005
  - PPVFR is located at New Delhi
  - PPV&FR is a kind of hybrid rights
  - It includes Farmers Rights
  - Protection of new varieties, extant varieties, farmer varieties, and common knowledge varieties and EDV
- **Extant variety:** available in India
  - Farmers' variety
  - A variety about which there is a common knowledge
  - Any other variety in public domain

Registration of New Variety

- New Variety: A new variety can be registered if it conforms to Novelty, Distinctiveness, Uniformity and Stability. A new variety shall be deemed to have

- Novel if the propagating or harvested material of the variety not sold or otherwise exploited for

	India	Outside India
Trees & Vines	> 1 year	> 6 year
Other than Trees & Vines	> 1 year	> 4 year

- Essential requirements qualifying varieties for protection varieties: Novelty, Distinctness, Uniformity, Stability (N-DUS)
- Distinctiveness (for atleast one essential character from all varieties of common knowledge)
- Uniformity (sufficiently uniform in essential characters) and
- Stability (characters shall unchanged over generations
- Total DUS centers in India: 107
- EDV: (Essentially Derived Variety): initial variety
- VCK: (Variety of Common Knowledge), Variety has not been released and notified under the Seed Act, 1966.
- VCK: Not released and notified under the Seeds Act, 1966 but is well documented through publications and is capable of satisfying the definition of 'variety'.
- UPOV: International Convention for the Protection of New Varieties of Plants, Geneva, established at 1968, Switzerland
- UPOV, 1991: Grants to provide and promote an effective system of plant variety protection
- Bioprospecting: is the search for commercially valuable biochemical and genetic resources in plants, animals and microorganisms.
- Biopiracy: is the theft or usurpation of genetic materials especially plants and other biological materials by the patent process.
- TRIPS: Trade Related Intellectual Property Rights (it cover IPR relates aspects)
- TRIPS: is landmark in the evolution of international intellectual property protection systems
- World Trade Organisation (WTO), 1995, Rome
- Word Intellectual Property Organisation (WIPO), Geneva, Switzerland
- Bioversity International is located at, Rome, Italy, 1974
- International Network for the Improvement of Banana and Plantain (INIBAP), France, 1994
- National Bureau of Plant Genetic Resources (NBPGR), IARI, New Delhi
- M.S. Swaminathan Research Foundation, Chennai, Tamil Nadu, 1988

- National Biodiversity Authority (NBA), Taramani, Chennai, Tamil Nadu
- Documentation and codification of traditional knowledge in india: TKDL
- TKDL: Traditional Knowledge and Digital Library, CSIR
- Copy Right Office, New Delhi
- Patent office (PO), Kolkata
- Indian Patent Act, 2005
- Geographical indication: is a sign or mark that is attributed to a good of any category (agricultural good/manufactured/industrial good etc.)
- Geographical indication of goods (Registration and protection) act, 1999, Rules, 2003
- Geographical indication (GI) office, Chennai, Tamil Nadu
- CBD: Convention on Biological Diversity, 1992
- First legal mechanism dealing with biodiversity in india: Conventional on Biological Diversity (CBD)
- CBD: it provides the facility of prior informed consent (PIC) or material transfer agreement (MTA)
- CBD signed during the Earth Summit at Rio de Janeiro, 1992
- CBD come into force 1993
- Biological Diversity Act, 2002
- Biological Diversity Act Rules, 2003
- GURT: Genetic Use Restriction Technology *e.g.* Terminator gene
- Final approval or release transgenic crops apex: GEAC (Genetic Engineering Appraisal Committee) under the Ministry of Environment and Forestry
- Guidelines toxicity and allergeicity Protocol given by OECD
- OECD: Organization for Economic Cooperation and Development, is located at France
- Transgenic biosafety protocol: Cartagena Protocol, 2003
- *Ex-situ* conservation: Gene bank or repositories, Botanical garden, tissue culture bank
  - Long storage of seeds, cryobank, DNA bank, Herbal seed
- *In-situ* conservation: On farm condition, wild relatives under natural condition
  - Biosphere reserve, National Bank
- **Crops introduced and naturalized in India**
  - Arabs: Clove, coriander
  - British: Cocoa, coffee, cashew nut, strawberry and blueberry

- China: Tea
- Latin America: Rubber, pineapple

+ National Gene Bank (NGB), 1983, New Delhi
+ Total agro biodiversity hotspots in india: 22
+ Citrus Gene Sanctuary (NOKREK Biosphere Reserve), Meghalaya
+ Sanctuary of orchids and rhododendron: Sikkim
+ National Herbarium of cultivated Plants at NBPGR, New Delhi
+ Indian national plant genetic resources management system is National Active Germplasm Sites (NAGS), ICAR
+ National Agriculture Science Museum (NASM), New Delhi
+ Nagoya Protocol, 2010: the fair and equitable sharing of benefits arising out of the utilization of genetic resources, including by appropriate access to them.

3. Protected Cultivation of Horticultural Crops

♣ Total area under green houses cultivation of horticultural crops in India: around 1000 hectares

♣ Greenhouse: Cultivation of plants under partly controllable environments comprising a superstructure (normally a metal or wood framing) and covered with transparent or translucent materials.

♣ Cladding materials: Coating of greenhouse (aiming at modifying the spectral transmittance, the reflectance, or the condensation, and dust accumulating properties)

- Glass (superior light transmission and heat retention), Plastics (cheaper but are less durable, poorer light transmission) and Polycarbonate

♣ Glass houses: very popular in Netherlands (Northern Europe)

♣ The commercial greenhouse orientation always east–west direction to get more light during winter months

♣ Most even light distribution occurs when the house is orientated north–south direction

♣ Light losses during the winter months in temperate climates are around 30%

♣ Ventilation is essential to control temperature and relative humidity

♣ Shading is used to reduce the incoming radiation

♣ Automatic systems to control temperature, ventilation and lighting

♣ Polytunnels: steel hoops set in the ground and clad with polythene. used in nursery

♣ Low tunnels (with wire hoops 30 to 50 cm high) are commonly used to protect rows of vegetables

♣ Low tunnels allow for a temporary protection of crops

♣ Cold frames are mainly used to raise plants from seed and to harden off plants from the greenhouse ready to be planted outdoors

♣ Floating mulches are lightweight coverings laid loosely over a row or bed of plants. protection from frost

♣ Netherlands, more than 90% of the greenhouses are covered with glass

♣ In China, plastic film is by far the most commonly used covering material

♣ Venlo type of greenhouse design is most widely used greenhouse type in the world

♣ Plastic films most widely used greenhouse covering material in the world

♣ NPCL: National Committee on Plasticulture Applications in Horticulture, 1981

♣ CPCT: Centre for protected cultivation is located at IARI, New Delhi.

♣ Polyethylene film: widely used in green houses

♣ Highest light transmission % of glazing materials: Polyethylene

♣ Low cost or naturally ventilated green houses: Suitable for cucumber

♣ Walk in tunnels: Low cost semi- permanent protected structures e.g cucurbits

♣ Insect net proof houses used for virus free crop production: Tomato and sweet pepper

♣ Rain shelters: Protection tomato plants against the impact of heavy rainfall

♣ Most popular type of green houses: Gutter connected structure

♣ Reduction of greenhouse temperature by using evaporative cooling method

♣ Optimum CO_2 for crop high yield: 1000-2000 ppm

Plastic low tunnels or row covers:

★ Structures laid in open field to cover rows of the plants with transparent plastic film

★ Simple and low cost structures for off season vegetable production n open field conditions

Net houses:

★ Shade nets: Prepared from HDPE (High density polyethylene) shade intensity varies between (25-75 %)

★ Insect proof nets: 40-60 mesh size (Free from viruses)

Plastic mulches:

★ Coloured plastic mulch: Reduce the insect damage

★ Yellow mulch: Repels the whitefly

★ Black plastic mulch: Used for soil moisture conservation and weed control

★ Transparent mulch (30-40 micron thickness): Increase the soil temperature (Soil solarization)

Lighting in green houses:

1. PAR: Photosynthetically active radiation (PAR, 400-700 nm)
   - Important for photosynthesis , production and crop development
2. UV: Ultraviolet radiation
   - UV-A (315-400 nm)- influences the development leaf and stem
   - UV-B (300-315 nm) – influence the formation flower colour
3. NIR: Near infrared radiation (wavelength 700-3,000 nm)
   - responsible for heating in green houses, highly useful for temperate countries
4. FIR: Far infrared radiation (wavelength 3,000-1,00,000 nm)
   - causes the greenhouse effect

Plastic films:

- The most applied flexible plastics for horticultural purposes
- Low density polyethylene (LDPE) films, like polyethylene (PE) with UV-stabilization, Polyethylene infrared (PE-IR) films
- Low tunnels: Temporary, unheated structures are used for cucurbits
- Low tunnels are ideal for the early production of many vegetable crops
- Open roof green houses were developed by Art Van Wingerden in 1990
- Open greenhouses protects from rain and hail

1. Protected cultivation of fruits :

Commercial orchards grown in pots

- Single stem fruits: Banana, papaya, pine apple
- Branched stem: Strawberry, mango loquat, peach & nectarine, grapes
- Apricot: Choicest variety for protected cultivation in china: gold sun
- Largest producer of banana under green houses: Morocco and Spain
- Suitable banana cultivar for protected cultivation: Grand Nine (G-9)
- Plastic houses are suitable for cultivation of strawberry
- Leading producer of grapes under protected cultivation: China (Variety: Kyoho)
- Most common fruit for protected cultivation: strawberry
- China is the leading producer of strawberry

Propagation structures:

A. Green house:

It is a house covered with glass or polythene for protection against adverse climatic conditions as well as to provide optimum environment for growth of the plants

B. Hot beds:

- Important plant growing structure
- Used for growing small tender seedling and rooting of cuttings

C. Cold frame:

- It is a small and mobile like glass structure, used to cover the ground bed
- Widely used for hardening of rooted cuttings

D. Lath house:

- It provides shade to young tender seedlings or rotted cuttings
- Highly used for hardening of seedlings

E. Net house:

- Suitable for shade loving plants *e.g.* Cacti, orchids

F. Mist chamber: Ideal technique for rooting of leaf cuttings

G. Low cost poly houses:

- It is a framed or an inflated structure covered with transparent polythene(partial control of environment and easy cultural operations
- Low cost polyhouses: Do not have environment control
- High cost polyhouses: It includes heating, cooling, drip irrigation and fertigation techniques
- Common plastics: UV stabilized 200 micron thickness
- Controlled polyhouse suitable vegetables: Tomato, cucumber, capsicum, okra, summer squash and bitter gourd
- Poly houses gives 5-6 times higher production compared to open field

2. Protected cultivation of vegetables:

★ **Cucumber:** Suitable varieties should have gynoecious and parthenocarpy traits

★ **Summer squash:** Bushy type

★ **Musk melon:** Most of the commercial varieties are andromonoecious types

Tomato:

- ♣ Commercially followed training system: Single stem
- ♣ Cluster thinning (once in a week) important for green house tomatoes
- ♣ Perfect pollinators: Bumble bees
- ♣ Suitable plant type for green house: Indeterminate varieties
- ♣ Ideal temperature for proper colour development: 18°C
- ♣ Optimum night temperature for fruit setting: 16-22°C duration of greenhouse tomato: 10-11 months, plant height 30-40 feet

Suitable varieties for protected cultivation in India

Crops	Specific types	Varieties
Tomato	Beef stalk varieties: (180-250g)	Trust, Match
	Big fruit variety(120-150g)	Daniela, FA-179, FA-189
	Cherry tomato: 12-20g, High TSS 6.8-7.0 %	BR-124, HA-818, T-56
	Suitable Indian varieties	Arka Vardan, Arka Vishal, Naveen
Capsicum		Red: Indira, Pusa Deepti
		Yellow: Orobellee, Golden Summer
Cucumber	Gynoecious varieties	Hasan, Sarig, Dinar
	Parthenocarpy varieties	Satis Almir
Musk melon	-	Arava
Summer squash	-	Australian Green, Pusa Alankar, Goldy

High tech nursery for vegetable crops:

★ Suitable combination media for root medium: Coco Peat, vermiculite and perlite: 3:1:1

Rooting media for plug tray nursery:

★ Coco-peat: Good drainage and porosity

★ Perlite: Neutral (volcanic origin)

★ Vermiculite:

♣ Chemically hydrated magnesium aluminium silicate

♣ Rich in Ca, Mg

Vegetable grafting:

★ Grafted vegetables popular in Japan and Korea

★ Leading grafted vegetable in the world: Water melon

★ Recommended light level for grafting acclimatization: 3-5 lux

★ Intergeneric grafting popular in cucurbits

Cucurbits:

★ Most widely used cucurbit rootstock: Shintozwa (Suitable for cucumber, melon and water melon)

★ Shintozwa is derived from (*C. maxima* × *C. moschata*): Resistant to fusarium wilt

Brinjal:

★ Interspecific grafting popular in brinjal

★ Commercial brinjal rootstock: *Solanum torvum*, *Solanum integrifolium* (Resistant to *Verticillium* and *Fusarium* wilt)

3. Flower crops:

★ Green houses for commercial floriculture were 1st established in India 1965 Indo-American Hybrid Seed (IAHS), Bangalore

★ Kerala is the leading protected cultivation of orchids

★ Ridge of the green houses always oriented in North-South (N-S) direction (avoiding sun scorching)

★ Most suitable green houses in Indian condition: Quonset type, multispan type

★ Most suitable green house for hilly regions: Gable type

★ Portable mini tunnels suitable for nursery plants

★ Fan and pad system is relies on evaporative cooling principles

★ Relative humidity (RH) for orchid cultivation: About 50%

Suitable Shade nets for foliage plants:

♣ Red and grey net: *Codiaeum*

♣ Grey net: *Hosta*, *Livistonia*, *Monstera*

4. Hydroponics in Horticultural Crops

- The term hydroponics was derived from 2 Greek words: *hydro*-water and *ponos*-labour
- Hydroponics: science of growing plants without the use of soil, but by the use of an inert medium, such as gravel, sand, peat, vermiculite, pumice, perlite, coco coir, sawdust, rice hulls, or other substrates, to which is added a nutrient solution containing all the essential elements needed by a plant for its normal growth and development
- Father of hydroponics: Dr. William F. Gericke, University of California, USA
- Hydroponics was 1st developed on commercial scale by W.F. Greicke, University of California, USA (1930)
- Hydroponics communalized in 1960-70's
- Soil less culture: Growing plants in the media other than soil
- Soilless culture techniques: Nutrient Film Technique (NFT), Tube culture and Aeroponics
- In India 1st introduced at Kalimpong, Darjeeling District, West Bengal
- Hydroponics has 3 methods: Water culture, Drip culture and Gravel culture
- Drip culture is also known as "sand culture"
- NFT: growing plants in a shallow stream of nutrient solution continuously circulated along plastic troughs or gullies
- Growing of plants in solid rooting medium watered with a complete nutrient solution, which is more accurately called aggregate culture
- Aggregate culture: using inert solid medium e.g. rockwool , perlite , polyurethane foam , duraplast foam or expanded clay aggregates
- Rockwool slabs are a very successful way of growing tomato, cucumber, pepper, melon, lettuce, carnations, roses, orchids and strawberry
- Maximum area under hydroponics country: Israel
- First crop raised in hydroponics: Tomato
- Suitable fruit crops for hydroponics: Strawberry, raspberry
- Optimum pH of solution: 5.2-6.5
- Nutrient solution replaced once in 4-6 days interval

Soilless mediums:

Commercial media used in hydroponics

Peat

- *Partially decomposed aquatic, marsh, bog, or swamp vegetation*

- Three types of peat (peat moss), reed sedge, and peat humus used
- Peat moss is the least decomposed and is derived from sphagnum, hypnum, or other mossses
- High moisture-holding capacity (10 times its dry weight), high in acidity (pH 3.8-4.5)
- Sphagnum moss dehydrated young residue or living portions of acid-bog plants in the genus *Sphagnum*, such as *S. papillosum*, *S. capillacium*, and *S. palustre*.
- It is relatively sterile, light in weight and very high water-holding capacity
- Peat (acidic in nature) widely used medium in soilless culture

Vermiculite

- Vermiculite is a micaceous mineral
- Hydrated magnesium-aluminum-iron silicate
- Very light in weight, neutral in reaction with good buffering capacity
- Hold nutrients in medium

Perlite

- Siliceous material, originated from volcanic regions, mined from lava flows
- Perlite will hold three to four times its weight of water
- Neutral soil with a pH of 6.0-8.0
- ▾It is most useful in increasing aeration in a mixture, very rigid structure

Coco coir

- Coco coir comes from coconut palm
- Coir is the fiber from the husk
- Adds to its porosity and gives better aeration than peat
- pH 5.7-6.3
- This coir pith is biodegradable, used in mulching and hydroponics

Nutrient film technique (NFT):

- ★ True hydroponics system
- ★ The plant roots are exposed to nutrient solution e.g. Tomato, cucumber

Aeroponics:

- ★ The plants are grown in trough or container; the roots are suspended and sprayed nutrient mist

★ Aeroponics: suitable for short stature vegetables e.g. Lettuce, spinach, potato (mini tuber production)

Aquaponics: It is a combined structure of growing fish and plants

5. Mineral Nutrition in Horticultural Crops

★ **Essential nutrients: 17**

- ✦ Basic nutrients: C, H, O
- ✦ Macro nutrients: N, P, K, Ca, Mg, S
  - ✦ Primary nutrients: N, P, K
  - ✦ Secondary nutrients: Ca, Mg, S

★ Micro nutrients: Fe, Zn, Cu, B, Mo, Cl, (Ni : 17th essential nutrient)

★ **Mobility of nutrient in soil**

- ✦ Mobile: SO_4^{-2}, B, Cl, Mn, N (NO^{-3})
- ✦ Less mobile: NH4, K, Ca, Mg, Cu
- ✦ Immobile: P, Zn

★ **Mobility of nutrient in plants:**

- ✦ Highly mobile: N, P, K
- ✦ Moderate mobile: Zn
- ✦ Less mobile: S, Mn, Cl, Mo, Cl
- ✦ Immobile: Ca, Fe, B

Function of nutrients:

- ♣ Basic structure of plant: C, H, O
- ♣ Energy storage and transfer: N, S, P
- ♣ Regulation and carriers: K, Ca, Mg
- ♣ Enzyme activation and electron transport: Fe, Mn, Zn, Cu, B, Mo, Cl

Nutrient availability in relation to soil reactions:

- ♣ Slightly acidic to strong alkaline soil: N, P, K, S
- ♣ Slightly acidic to medium alkaline soil: Ca, Mg
- ♣ Medium acidic to slightly acidic: Cu, Zn
- ♣ Strong acidic to slightly acidic: Fe, B
- ♣ High acidic soil: Mn
- ♣ High alkaline soil: Mo

Leaf or tissue analysis

- Nutrient management of fruit crops is determined by leaf analysis
- First reported by Smith, 1966
- Leaf sampling of various tissues used in fruit crops

Fruit crops	Index tissue
Petiole	Banana, grapes, papaya
Leaf	Citrus, mango, pomegranate, sapota apple, guava
Leaf base	Pine apple

- Rhizosphere: environment for bacteria, fungi, mites and nematodes situated around the root
- Phyllosphere: environment on the leaf and stem.
- ♣ The pH scale is a means of expressing the degree of acidity or alkalinity
- ♣ Most plants requires ideal growing conditions soil pH 6.5 (slightly acidic)
- Calcicoles, or 'lime-loving' plants
- Calcifuge or 'lime-hating' plants e.g. Rhododendrons
- ♣ Alkaline soil: presence of large quantity of lime
- ♣ Acid rain (polluted rain and snow) is directly harmful to vegetation
- ♣ Calcium carbonate is the most common liming material
- ♣ Limestone: cheap liming material, easy to store and safe to handle
- ♣ Calcium oxide: quicklime or caustic lime
- ♣ Calcium hydroxide: hydrated or slaked lime

1. Nitrogen:

- Plants utilize the soluble nitrogen from the soil water as nitrates and ammonium ions
- ✦ Nitrogen is taken up by plants as the form of nitrate and lesser extent the ammonium ion.
- ✦ Nitrates are mobile in the soil, which makes them vulnerable to leaching
- Ammonia is first converted to nitrites by *Nitrosomonas* spp
- ✦ Nitrites converted to nitrates by *Nitrobacter* spp
- ✦ Ammonifying and nitrifying bacteria live in aerobic conditions

+ Many anaerobic bacteria utilize nitrates convert into gaseous nitrogen
+ Denitrification: loss of nitrate from the soil, serious problem in well-fertilized, warm and waterlogged lands
+ Plants cannot utilize gaseous nitrogen, it can be converted to plant nutrients by some micro-organisms (Azotobactor) free-living bacteria that obtain their nitrogen requirements from the air
+ Plants absorb nitrogen from soil: Nitrate (NO_3), extremely soluble, leaching problem
+ Nitrates are mobile in the soil, which makes them vulnerable to leaching
+ Nitrogen fixing legumes e.g. cowpea, indian bean
+ Symbiotic nitrogen fixing microorganism: *Rhizobium, Actinmyces alni*
+ Non-symbiotic nitrogen fixing microorganism: *Azotobacter, Clostridium*
+ **Function**: Structural constituent of cell
+ **Deficiency**: Older leaves, Stunted plant, late flower production
+ **High level of N**: Degrain in banana, Riceyness in cauliflower
+ Ammonium nitrate is now commonly used in horticulture crops
+ Urea has a very high nitrogen content and quickly releasing N fertilizer
+ Ammonium sulphate: very high acid reaction

Nitrogen fertilizers	Nitrogen content (%)
Urea	46
Ammonium sulphate	20.6
CAN (Natural fertilizers)	25
Anhydrous ammonia	81.5

♣ The term C: N ratio was first coined by Karaus and Kraywill in 1919
♣ C: N ratio (Carbon: nitrogen) concept was given by Klebs (1913)
♣ Low C: N ratio: Promotes vegetative growth
♣ High C: N ratio: Promotes flowering
♣ Optimum C:N ratio 15-20:1

2. Phosphorous:

★ Phosphorus is taken up by plants in the form of the phosphate anion $H_2PO_4^{3-}$

★ Extremely insoluble
★ Organic sources of Phosphorus e.g. bones, now phosphate fertilizers mainly derived from rock phosphate ore
★ Citric soluble phosphate: slow acting forms: rock phosphate, bone meal and basic slag
★ Superphosphate and triple superphosphate widely used in horticulture crops
★ Mycorrhizae (fungi) close association with roots: facilitate phosphorus uptake e.g. Rosaceae

Functions:

★ Structure component of membrane system (Mitochondria, Chloroplast)
★ Essential constituent RNA, cDNA, NADP, ADP, ATP
★ Enhance nodule formation in legume crops

Deficiency: Anthocyanin pigmentation in leaves
Excessive P: Pencil strip in celery

Phosphorous fertilizers	P content (%)
SSP	18-20
Rock phosphate	20-38
Superphosphate	18-20
Triple superphosphate	47

3. Potassium:

★ Potassium is taken up by the roots as the potassium cation (K^+)
★ Balanced vegetative growth: nitrogen to potassium ratio for most crops: 1:1, roots and legumes crops: 2:3
★ Potassium supplies are abundant some plants, take up 'luxury' levels, i.e. more than needed for their growth requirements (luxury consumption)
★ Potassium is readily soluble in water

Functions:

♣ Regulation of opening and closing of stomata
♣ Essential for photosynthesis
♣ Maintaining cytoplasm pH
♣ Reduction of lodging of plants
♣ Resistant to crops
♣ Formation of starch

♣ Translocation of sugars e.g. potato, root crops

Deficiency:

✦ Older leaves to new leaves

✦ Necrotic spots in leaves

✦ Marginal scorching e.g. Banana, Black speck in cabbage

Potash fertilizers	K content (%)
MOP	60
Potassium sulphate	50 (Sulphur 17.5%)

4. Calcium:

▪ Gypsum (calcium sulphate) can be used desirable to increase calcium levels in the soil

Functions:

♣ Maintenance of chromosome structure

♣ Regulation of enzyme activity

♣ Plants: Calcium pectate

♣ Seeds: Calcium phytate

Deficiency:

✦ Symptoms: Younger leaves

✦ Bitter pit of apple

✦ Blossom end rot of tomato, watermelon

✦ Internal fruit break down in mango

✦ Pulp softening in papaya

✦ Cork spot of apple

✦ Jonathan spot of apple

✦ Stalk necrosis in grapes

5. Magnesium:

★ Essential for chlorophyll (Magnesium porphyrin)

★ **Deficiency:** Older leaves

★ Blueing, brown marbling in leaves and petioles

6. Sulphur:

★ Functions: Essential for sulphur containing amino acids *e.g.* Cysteine, cystine, methionine

★ Improve the oil quality e.g. Oil seed crops

Role of micronutrients

Element	Functions	Deficiency	Examples
Fe	Nucleic acid synthesis Synthesis of chlorophyll	✦ Common in calcareous soil and limestone ✦ High pH soil (alkaline) ✦ Younger leaves	♣ Presence of large quantities of calcium and this 'lime induced' chlorosis (yellowing) ♣ Interveinal chlorosis
Mn	Electron transfer in photolysis	Middle and older leaves	Interveinal chlorosis Marshy spot in garden pea Green blotch in persimmon
Zn	Synthesis of RNA, IAA Stability of protein membrane Important for anaerobic respiration crops	✦ New leaves ✦ Reduction of internode length ✦ Common in sodic soil and calcareous soil	Citrus: Mottle leaf foliocellosis or frenching or frenched leaf or mottled leaf
Cu	-	Cupping of leaves	Dieback and exanthema in citrus Whipping in banana
B	Transfer of sugars Pollen germination and pollen tube growth Regulation of stomata opening	-	Sugar beet: Brown heart or heart rot Cauliflower: Hollow stem, browning of curd Apple: External and internal cork Coconut: Button shedding Citrus: Hard fruit or stony [illegible] Grapes: Hen and Chicken [illegible] Aonla: Fruit necrosis Persimmon: Calyx cavity

			Celery: Cracked stem Tomato: Fruit cracking
Mo	Essential for nitrogenase enzyme	-	Whip tail of cauliflower
Ni	Seed viability, root nodulation	-	Legume vegetables

Physiological and nutritional deficiency symptoms

- Bronzing: development of bronze or copper colour in plant tissue
- Chlorosis: loss of chlorophyll resulting in loss of green colour leading to pale yellow tissues
- Decline: onset of general weakness as indicated by loss of vigour, poor growth and low productivity
- Die-back: collapse of the growing terminal tip affecting the younger leaves
- Firing: burning of tissue accompanied with dark brown or reddish brown colour
- Lesion: a localized wound of the leaf/stem tissue accompanied with loss of normal colour
- Necrosis: death of tissues
- Scorching: burning of the tissue accompanied with light brown colour resulting from faulty spray, salt injury etc.

Fertilizers:

- Fertilizers: applying nutrients to the soil to enhance plant growth
- **Types of fertilizer**
  - Organic fertilizer: derived from living organisms
  - Inorganic fertilizers: derived from non-living material
  - Straight fertilizer: These contain only one of the major plant nutrients: nitrogen, phosphorus, potassium or magnesium e.g. Ammonium nitrate
  - Compound or Complex fertilizer: These fertilizers contain two or more nutrients bonded together, e.g. DAP (18:46:0)
  - Mixed/blended – Produced by mixing two or more straight fertilizers together e.g. 2 or more nutrients
- Preferable nitrogen fertilizer for alkaline soils: Ammonium sulphate
- Hygroscopic (not fit for storage) nitrogen fertilizer: Ammonium nitrate

- CAN: neutral fertilizer
- Ammonium chloride: Not suitable for tomato, tobacco (because of chlorine toxicity)
- Popular nitrogen fertilizer: Urea
- Murate of potash (MOP) affect the quality of the crops: e.g. Potato, tobacco
- MOP is known as potassium chloride (KCl)
- Potassium nitrate: breaks the seed dormancy (KNO_3)
- Fertigation: first started in the late 1960's in Israel with the development of drip irrigation and now 75% of the irrigated area is fertilized by fertigation.
- Starter solution: fertilizers solutions (N:P:K with a ratio of 1:2:1 or 1:1:2) applying at young seedlings at the time of transplanting

Fertilizers application methods

- **Base dressing:** mixed into growing media, usually before planting
- **Surface broadcast:** scattered on prepared soil surface, or broadcast on the surface to be cultivated-in during the final stage
- **Top dressing:** fertilizers added to the soil surface but not incorporated. Nitrogen fertilizers most frequently applied by this method
- **Liquid feeding:** application of fertilizer diluted in water to the root zone or fertigation if incorporated in irrigation system or hydroponics production systems
- **Foliar feeding:** application of a liquid fertilizer in suitably diluted form to be taken up through leaves, normally to correct deficiencies sprayed onto leaves

Bulky organic matter

- Maintaining organic matter and humus levels e.g. Compost, straw, farmyard manure, bark, peat

Green manure crops:

- ★ Green manuring is the practice of growing plants primarily to develop and maintain soil structure and fertility
- ★ Legume: Sun hemp (*Crotalaria juncea*): Drought tolerant legume
- ★ Dhaincha or Koliniji (*Sesbania aculeata*): Flood tolerant green manure crop, alkaline or water logged soils
- ★ Wild indigo (*Tephrosia purpurea*): Drought tolerant legume
- ★ Fastest nitrogen fixating green manure crop: *Sesbania rostrata* (Stem and root nodul

Green leaf manure crops:

- Application of green leaves and tree twigs, shrubs and herbs plants collected from different places waste lands and forest.
- Green leaf manures (GLMs) are organic manures made from leaves collected from all available sources and used to supply essential plant nutrients to the soil and increase soil fertility
- e.g. Neem, Mahua, Gliricidia (*Gliricidia maculata*), Calotropis, Karanj (*Pongamia pinnata*), Tephrosia

Concentrated organic manure: Oil cakes, materials of animal origin

Biofertilizers

- Microorganisms used as a biofertilizers
- Symbiotic: Rhizobium (Legume crops): *e.g.* Pulse, legumes, Azolla (Fern-anabaena): *e.g.* rice
- Rhizobium is a bacterial bio-fertilizer
- Non-symbiotic, free living bacteria: Azotobacter e.g. Vegetable crops
- Azotobacter fixes nitrogen about 20-30 kg/ha
- Associative symbiosis bacteria: Azospirillum *e.g* Rice, sugarcane
- Azospirillum (heat tolerant) more suitable for non-leguminous crops e.g. cereal crops
- Blue green algae or cyanobacteria (nitrogen fixing) e.g. Anabaena
- Blue green algae commercially utilized in rice
- Phosphobacteria or Phosphatic bio-fertilizers: *Pseudomonas*, *Bacillus*, *Penicillium*, *Aspergillus*
- Arbuscular Mycorrhiza (AM): association between plant roots and fungal mycelia (mutualistic symbiosis)
- AM fungi: e.g. Acaulospora, Gigaspora, Glomus
- AM: mobilize phosphates and other micronutrients like zinc, boron and molybdenum

6. Organic Farming in India

★ The term 'organic' was first used in relation to farming by Northbourne (1940) in his book Look to the Land

★ Australia is leading organic farming country in the world

★ Leading organic state in India: Sikkim

★ Methods of Organic farming

♣ Biodynamic farming: Aims to treat the farm as a living system

♣ Father of Biodynamic farming: Rudolf Steiner

♣ Rishi Krishi: Commonly practised in Madhya Pradesh

♣ Panchgavya: consisting of five products of cow

♣ Natural Farming developed by Mokichi Okada

★ Natueco farming- based on the principle of ecosystem networking of nature

Regulatory mechanisms in organic farming:

★ IFOAM: International Federation of Organic Agriculture Movements, conceptual support for a globally unified certification database

★ IFOAM (1972) is located at Bonn, Germany

★ APEDA (Agricultural and processed export development authority) comes under Ministry of Commerce

★ APEDA: Regulation of organic production and export under the brand name "India Organic"

★ National programme on organic production (NPOP, Ministry of Commerce and Industry as the apex body), 2002.

★ National Centre of Organic Farming at Ghaziabad

★ In India, standards and regulations developed by APEDA, Department of commerce, Ministry of commerce and industry in March, 2000, published as a NSOP.

★ National standard for organic production (NSOP)

★ NPOP is launched at 2001, it comes under FTDR act

★ Foreign trade development and regulation act (FTDR) is responsible for export requirement

★ Apex body of organic certification: National Accreditation Body (NAB)

★ Indian organic certification (IOC) process granted at world level during 2004

★ National centre for organic farming (NCOF) is located at Ghaziabad, U.P comes under Ministry of Agriculture

★ National Project on Organic Farming (NPOF) is started at 2004

★ NSOP: National standards for organic promotion

★ APOP: Association for promotion of organic products, Bangalore

GAP in horticulture

- GAP: Good agricultural practice
- GAP: practices that address environmental, economic, and social sustainability for farm processes and safe, quality food and non-food agricultural practices
- HACCP: Hazard Analysis and Critical Control Points
- *Codex Alimentarius*: leading food safety agencies

- Codex Alimentarius commission developed by FAO and WHO in 1963
- International Organisation for standardization (ISO), Geneva, Switzerland
- ISO 9000: concerned with quality management
- ISO 14000: Environmental management
- In India organic foods produced by organic standards of NPOP
- Demeter: Symbolize the biodynamic foods

7. Role of Plant Growth Regulators in Horticultural Crops

1. Auxin:

- Auxin name was given by Kogl
- Avena curvature test, oat coleoptile test: bioassay for auxin
- Auxins are produced in meristematic tissue such as root tips, shoot tips, apical buds, young leaves, and flowers

Precursor: Tryptophan

Types of Auxins:

1. Only known naturally occurring auxin in plants: Indole-3-acetic acid (IAA)
2. Synthetic auxins: IBA, NAA, 2, 4-D (herbicide for controlling selective broadleaf weeds)
   - 2, 4-D systemic herbicide

Site of auxin production: Shoot and root tips, young expanding leaves and seeds

Role of auxin in plants:

- Shoot: polarity is basipetal (toward the base of the stem and leaves)
- Root: polarity is acropetal (toward the tip)
- Promotes the **Apical dominance**
- Apical dominance: The main central stem of the plant is dominant over other stems
- Inhibition of lateral shoot growth
- **Phototropism**, the bending of the growing point of a plant toward light
- Rooting hormone to induce rooting (adventitious) in cuttings
- Stimulate the cell elongation
- Promotes or inhibits the growth of adventitious roots
- High amounts of auxin induce root formation in callus

Auxin Promotes Rooting.

2. Gibberellins (GA):

Helps in cell division.

- Precursor: Terpenoids
- Site of Gibberellins production: young leaves

Role of Gibberellins in plants:

- Stimulate the stem elongation, cell division (internode elongation)
- Promotes the seed germination (breaking seed dormancy)
- Tolerance to chilling
- Induction of flowering in long day plants
- Prevention of genetic and physiological dwarfism of plants
- Induces seedlessness in fruit crops
- Breaking dormancy (seed, tuber and shoot)
- GA stimulates bolting in rosette plants

Flowering:

- ★ Short days - vegetative
- ★ Long days - flowering
- ★ Short days + GA - flowering

GA synthesis inhibitors: Paclobutrazol (PBZ), Flurprimidol, Ancymidal

3. Cytokinins:

(Roots)

- ★ Cytokinins occur in embryonic or meristematic organs
- ★ Skoog and Miller coined the auxin–cytokinin hypothesis of plant morphogenesis
- ★ Natural cytokinin: isopentenyl adenine (IPA), and zeatin (Z)
- ★ Synthetic cytokinin: Kinetin, BA (Benzyl adenine)

Site of ~~Gibberellins~~ production: Root tips

Precursor: 5′-AMP (Isopentenyl group)

Role of cytokinin in plants

- Stimulate cell division and lateral bud development
- A high cytokinin-auxin ratio (i.e., low amounts of auxin, especially IAA) promotes lateral bud development
- Delaying senescence (Richmond long effect)
- Enlargement cells

- Differentiation of cells (interact with auxins)
- Induces the flowering in short day plants
- Cytokinins producing large amounts of callus tissue

Control of morphogenesis:

A. Ratio of cytokinin and auxin are important in determining the fate of the callus:

★ Callus + low (cytokinin/auxin) → Callus grows well, forms roots

★ Callus + high (cytokinin/auxin) → Callus grows well, forms meristem & shoots

B. In plant tissue cultures, cytokinin is required for the growth of a callus (an undifferentiated, tumor-like mass of cells)

★ Callus + auxin + no cytokinin → Little growth of callus

★ Callus + auxin + cytokinin → Callus grows well, undifferentiated

Tissue culture:

★ Mainly used for shoot and adventitious shoot multiplication

★ In shoot culture it encourage the growth of axillary buds

★ Auxin and cytokinin ratio is important for formation of adventitious shoot and root meristems

★ High cytokinin to auxin ratio: Induce shoot growth

★ High auxin to cytokinin ratio: Induce root growth

4. Abscisic acid (ABA):

- Naturally occurring plant hormone
- Stress hormone
- **Site of ABA production:** Terminal bud
- **Precursor:** Sesquiterpenoid pathway (Mevalonic acid)
- **Site of ABA production:** All organs

Role of Abscisic acid in plants:

★ Bud dormancy

★ Stimulates the closure of stomata

★ Induction and maintenance of dormancy

★ Disease resistance

★ Protecting cells from dehydration

5. Ethylene (C_2H_4):

- Gaseous hormone, ripening hormone

Precursor: Methionine

★ Stimulates shoot and root growth and differentiation (triple response)

★ Enhances the latex flow *e.g.* Rubber

★ Stimulates leaf and fruit abscission (Phytogerontological hormone)

★ Induction of flower *e.g.* Pine apple

★ Initiation of fruit ripening *e.g.* Citrus, Banana and Tomato

★ Stimulates flower and leaf senescence

Commercial growth retardants

- **Daminozide (Alar and B-nine):** plants that respond to it include poinsettia, azalea, petunia, and chrysanthemum
- **Chlormequat (CCC, cycocel):** Retards plant height in poinsettia, azalea, and geraniums
- **Ancymidol (A-Rest):** Effective in reducing height in bulbs, such as Easter lily and tulip, as well as chrysanthemum and poinsettia
- **Paclobutrazol (Bonzi):** used to reduce plant height in bedding plants including impatiens, pansy, petunia, and snapdragon
- **Maleic hydrazide:** used to prevent sprouting of onions and potatoes

8. Major Vitamins Present in Horticultural Crops

Vitamins	Scientific name	RDA/AI (mg/day)	Deficiency	Fruits	Vegetables
A. Fat soluble vitamins					
Vitamin A	β-carotene (Retinol)	0.8	Night blindness (nyctolopia) Kertaomalacia Xerosis	Mango, Papaya	Carrot, Sweet potato, Pumpkin
Vitamin D	Calciferol		Rickets Osteomalacia	-	-
Vtamin E	Tocopherol	15	-	Avocado, Mango	Spinach, Kale
Vitamin K	Phylloquinone		-	-	-

B. Water soluble vitamins					
Vitamin C	Ascorbic acid	82.5	Scurvy	Aonla, Guava, Citrus	Bitter green drumstick leaves
B1	Thiamine	1.15	Beriberi, Pellagra	Cashew	Chilli
B2	Riboflavin	1.2	Angular stomatitis	Bael, Papaya, Litchi	Fenugreek leaves
B3	Niacin	15	Dermatitis, Glossitis	-	-
B5	Pantothenic acid		-	-	-
B6	Pyridoxine	1.3	-		
B7	Biotin or Vitamin H		-	-	-
B9 (Folate)	-	0.40	Macrocytic anemia	Sweet orange, Mandarin	Cabbage, Kale, Broccoli, Green leafy vegetables
B12	Cobalamine	-	-	-	-

*RDA: Recommended Daily Allowance

*AI: Adult Individual

9. Biotechnology of Horticultural Crops

A. Micro propagation:

★ Micro propagation: In vitro multiplication of plants from small tissue (Explants)

★ Totipotency in plants: Vasil and Haberlandt (1964) [Ability of a cell to produce Plant]

★ Father of tissue culture: Dr. Gottlieb Haberlandt, German (1902)

★ Concept of *in-vitro* cell culture: Dr. Gottlieb Haberlandt

★ *In-vitro* multiplication of plants developed 3 stages by Dr. T. Murashige, University of California, USA

★ Meristem culture: Production of virus free plants

★ Meristem culture was successfully utilized in banana

★ Meristem culture is the most effective procedure for the eradication of phloem-associated viruses

★ Virus particles located in the phloem probably cannot invade the meristematic tissues because there is no cell differentiation in this zone

★ Chemotherapy which uses chemical compounds applied to in vitro plant or meristem cultures

★ Micro grafting or shoot tip grafting: used for overcoming graft incompatibility

★ Micro grafting: Development and multiplication of virus-free plants

★ Embryo culture: Overcome pre and post zygotic barriers, shortening breeding cycle & overcome seed dormancy e.g. Tomato

★ First successful embryo culture: Cherry embryo (1993)

★ Embryo culture or embryo rescue: e.g. grapes, peach, sweet cherry, Brassica

★ Double haploids: Production of 100% homozygous plants

★ Haploid induction 1st developed by Guha and Maheswari (1966) in *Datura innoxia*

★ Haploid is a plant with the gametic or *n* number of chromosomes.

★ Haploid plants develop from anther culture either directly or indirectly through a callus phase

★ Androgenesis

- ♣ is the process by which haploid plants develop from the male gametophyte
- ♣ most commonly utilized technology for DH production

★ Gynogenesis: Haploids are derived from the female gametophyte e.g. Sugar beet, onion, gerbera

★ Microspore culture: Involves isolating microspores from anthers before culture and is sometimes referred to as pollen culture. e.g. Brassica vegetables

★ Somaclones: Plants derived from any type of somatic cell culture

★ Somoclonal variation: Creation of novel source of variability by regeneration of callus culture

★ Protoplast fusion or somatic hybridization: Fusion of two somatic cells of different species, genera or family. To overcome the sexual incompatibility

★ Cybrids: Nuclear gene from one species and the cytoplasm from both parents to combine to produce cytoplasmic hybrids or cybrids

★ Main application of cybrids: Direct transfer of CMS from donor to recipient lines

★ Cybrids (Cytoplasmic hybrids): *e.g.* Citrus

B. Molecular Markers:

★ The basic concept of association of markers with quantitative traits first proposed by Sax 1923

★ The first concept of genetic map was presented by Alferd H Sturtevant,1913

★ The first genetic map published by in 1911 T.H. Morgan

★ To minimize the linkage drag, need to identification of flanking marker: Less than 5cM

★ The term markers assisted selection was first used by Beckmann and Soller 1986

★ 1st molecular marker: RFLP, 1980

★ Southern hybridization developed by S.M. Southern (1925)

★ PCR developed by Dr. Karry Mullis (1985)

Markers:

Definition: It is a heritable difference in nucleotide sequences of DNA at corresponding position of homologous chromosome of two different individuals, which follows the simple inheritance

Type of markers:

★ **Genetic markers:** is a sign or flags located near or tightly linked to the genes that controlling the trait

★ **Major genetic markers-**

- **Morphological markers:** The phenotypic characters are used as a marker e.g. Seed colour, leaf shape
- **Biochemical markers:** Allelic variants in enzymes
- **DNA markers:** Site variation in DNA sequence e.g. deletion/insertion

Classification of DNA markers based on their detection

1. PCR based marker: RAPD, SSR, DAF, AP-PCR
   - ✦ Single primer: DAF, AP-PCR, RAPD
   - ✦ Pair of primers: SSR, SCAR, STMS
2. Hybridization based marker: RFLP
3. Sequence based molecular marker: SNP
   - ✦ Random markers: RAPD, ISSR

★ **Monomorphic markers:** Markers that do not differentiate between genotypes

★ **Polymorphic markers:**

- Markers able to differentiate between the homozygotes and heterozygotes

Mode of gene action

★ *Dominant markers:* DNA are either present or absent

★ *Co-dominant markers:* Identify through the differences in size DNA

Classification of Marker Systems:

Marker system	Marker systems(abbreviations)	Useful/specific features
A. First-generation markers based on restriction fragment detection		
RFLP	Restriction fragment length polymorphism	Physical mapping of genes
B. Second-generation markers based on PCR		
RAPD	Random amplified polymorphic DNA	Gene tagging
AFLP	Amplified fragment length polymorphism	Gene tagging
SSR	Simple sequence repeat (microsatellite)	Highly informative marker
STS	Sequence tagged sites	Gene mapping
SCAR	Sequence characterized amplification region	Gene tagging & physical mapping
CAPS	Cleavage amplification polymorphism	Allelic diversity
C. Third-generation markers based on DNA sequencing		
SNP	Single nucleotide polymorphism	High throughput system
D. Genome scanning for expressed genes		
EST	Expressed sequence tag	
SRAP	Sequence-related amplified polymorphism	
TRAP	Target recognition amplification protocol	
E. Markers using array technology		
Microarrays	(arrangements of small spots of DNA fixed to glass slides)	Whole genome scanning
(DArT)	Diversity array technology	Dominant marker, germplasm characterization

Overview of Marker Systems:

Markers	Dominance	Level of polymer-phism	Number of detected loci	Reproduc-tibility	Important features
RAPD	Dominant	Low	Multiple loci	Low	Diversity analysis
ISSR	Dominant				Diversity analysis
AFLP	Dominant	Low	Multiple loci (High)	High	High resolution

RFLP	Co-dominant	Low	Single locus	High	Construction of linkage maps
SSR	Co-dominant	Very high	Single locus	High	F1hybrid purity test Diversity analysis
SRAP	Co-dominant				Gene tagging, linkage map
SNP	Co-dominant	High	Single locus	High (Bi-allelic)	High throughput system
STS	Co-dominant	High	Many alleles per marker		High throughput system
SCAR	Dominant/Co-dominant	-	Single locus	-	Derived from RAPD markers

Mapping Population:

Definition: Plant mapping populations are usually created from F_1 lines that are derived from two parents that show differing phenotypes for a target trait

- ★ NIL: Near Isogenic Line which are developed through repeated random backcrossing
- ★ NIL: Commonly used for mapping of QTLs
- ★ RIL: Recombinant inbred lines are the homozygous selfed or sib mated progeny of the individuals of an F_2 population up to F_7 - F_8
- ★ DH: Double haploid lines: an individual with the doubled chromosome number of the haploid line. Rapid derivation of homozygous lines
- ★ True breeding lines or permanent/immortal populations: RIL and DH
- ★ Short method to detect the QTLs is BSA (Bulked segregant analysis)

Mapping populations and their inheritance:

Mapping populations	Co-dominant markers	Dominant markers
F2	1:2:1	3:1
Back cross	1:1	1:1
RIL, DH	1:1	1:1

DNA finger printing or genotyping:

- ♣ It is a technology used to characterize and compare DNA sequences of any living organisms

Genetic mapping/linkage mapping/meiotic mapping:

- ♣ Determination of relative position of genes on a DNA molecule and of their distant between them

Marker assisted selection (MAS):

- ★ The term MABC coined by Hospital and Charcosset (1997)

MABC (Marker assisted backcrossing) have 3 strategies:

1. **Foreground selection:**
   - ✦ Markers used to assess the presence of the introgressed gene or QTL
   - ✦ The term coined by Tanksley (1983)
2. **Background selection:**
   - ✦ Markers used to accelerate the return to the recipient parent genotype at other loci
   - ✦ The strategy was proposed by Hillel (1990)
3. **Recombinant selection:** Selections of best back cross progeny with the target gene, using flanking markers

Linkage map/Genetic map:

- ♣ A genetic map is a representation of the genes on a chromosome arrayed in linear order with distances between loci expressed as percent recombination (map units, centi-morgans)
- ♣ It measured by centi-morgans (cM)
- ♣ One linkage map unit (LMU) is 1% recombination
- ♣ One map unit = one centi-morgans (cM) = 1% recombination between loci

Physical map:

- ♣ Describes the physical location of genes on chromosomes
- ♣ It measured by base pairs (bp)

Comparative mapping:

- ✦ Alignment of chromosomes of related species based on genetic mapping of common D markers
- ✦ Used for analysis of genes and QTLs

Orthologous genes:

Genes in different species that originated by vertical descent from a single gene of the common ancestor

Paralogus genes:

Two genes or clusters of genes at different chromosomal locations in the same organism have structural similarities indicating that they derived from a common ancestral gene

QTL mapping:

★ The term QTL first coined by Gelderman (1975)

- QTLs: quantitative trait loci – a region of a genome that is associated with an effect on a quantitative trait

★ Concept of quantitative genetics: R.A. Fisher, S. Wright, J.B.S. Haldane

- ♣ QTL-NILS- the QTL is located at within 10-30 cM in length
- ♣ Most common method of QTL mapping is interval mapping
- ♣ Ideal cM distance for QTL cloning is 2 cM or less
- ♣ Fine mapping of high resolution QTL: 25-100 Kb
- ♣ First tagged QTL in plants: *fw2.2* (Fruit weight: Tomato)

Genomics:

★ Genome: is the sum total of all an individual organism's genes. Thus, genomics is the study of all the genes of a cell, or tissue, at the DNA (genotype), mRNA (transcriptome) or protein (proteome) levels.

★ Genomics: The study of all of the nucleotide sequences, including structural genes, regulatory sequences, and non-coding DNA segments, in the chromosomes of an organism.

- o The term 'genomics' was coined by Dr. Tom Roderick

★ Structural genomics: describe the 3-dimensional structure of every protein encoded by a given genome.

★ Functional genomics: Understanding the function of genes and other parts of the genome

- o Proteomics: A complete set of protein present in s single cell
- o Transcriptomics: A complete set of mRNA present in a single cell
- o Metabolomics: A complete set of metabolites present in a single cell

★ Comparative genomics: the study of the similarities and differences in structure and function of hereditary information across taxa

DNA sequencing: It includes several methods and technologies are used for determining the order of the nucleotide bases A, G, C and T in a molecule of DNA

Sequencing technologies:

★ **Second generation sequencing:** Illumina system and Pyro-sequencing

e.g. Roche GS20, Roche GS FLX, SOLiD system, and Sanger sequencing

★ **Third generation sequencing:** True single-molecule sequencing (tSMS)

C. Completed and Released Genome Sequences in Fruit And Vegetable Crops:

Fruit crops

Fruit crops	Genome size	Mapping population	Fully completed
Grapes	500 Mbp	Pinot Noir	2007
Papaya	742.3 Mbp	Sun Up	2007
Apple	372 Mbp	-	2010
Peach	220-230 Mbp	-	2010
Strawberry	250 Mbp	*Fragaria vesca*	2011
Banana	523 Mbp	*Musa acuminata*	2012
Pear	512Mbp	*Pyrus bretschneideri*	2012
Date palm	605.4 Mb	Khalas	2013
Kiwi fruit	616.1 Mb	-	2013
American cranberry	470 Mbp		2014

Vegetable crops

Vegetable crops	Genome size	Mapping population	Fully completed
Potato	844 Mbp	RH 89-039-16 (Diploid heterozygotes), DM-1-3-516R44 (Double monoploid)	2011
Chinese cabbage	283.8 Mbp	Chiifu-401-42	2011
Tomato	900 Mbp	'Heinz 1706	2012
S. pimpinellifolium	739 Mbp	LA1589	2012
Cucumber	367 Mbp	Chinese Long " 9930"	2009
Melon	450 Mbp	Double-haploid line (DHL92)	2012
Watermelon	375 Mbp	-	2012
Sugar beet	567	-	2013
Hot pepper	650.2 Gb	*C. annuum* cv. CM334	2014
Cabbage	630 Mbp	02–12	2014
Radish	402 Mbp	-	2016
Carrot	421.5	-	2016
Spinach	498 Mb	Sp75	2017

***Mbp:** Mega base pair

- Potato (1st sequenced tuber vegetable)
- Watermelon (1st sequenced vegetable)

Trangenics in Horticultural Crops:

- Transgenics /GMOs - Genetically modified organisms/LMOs - Living modified organisms/GEOs - Genetically engineered organisms
- Transgenics: Means transfer of genetic material (DNA fragment carrying known genes) from across the biological systems through *in-vitro* techniques
- 1st transgenic plant was developed in tobacco 1983
- 1st transgenic engineering company Genentech established 1976
- 1st transgenic variety "Flavr Savr" in tomato developed by Calgene for enhancing shelf life
- 1st transgenic crop commercially cultivated in India: Cotton, 2002

Transgenic status in world:

- Leading crops: Soya bean > Maize > Cotton
- Leading traits: Herbicide tolerance > *Bt* insect resistance
- Leading countries: USA > Argentina > Canada

Methods of gene transfer

- Vector gene transfer: Agrobacterium mediated transfer, agro-injection , viral vector
- Direct gene transfer: Microinjection, particle bombardment
- The Cartagena protocol on bio-safety (CPB) originated from the Convention on biological diversity (CBD) in 2000 and came into force in 2003
- Transgenic varieties are approved by GEAC (Genetic Engineering Appraisal Committee)

Genome editing

- Genome editing comprises predicted changes in the gene sequence or precise insertion of exogenous DNA with the goal of inactivating gene(s), generating functional alleles, replacing mutant alleles or site-specific transgene integration.
- It alter DNA sequences and modify gene function
- *CRISPR*: stands for clusters of regularly interspaced short palindromic repeats.
- CRISPR is shorthand for "CRISPR-Cas9." CRISPRs are specialized stretches of DNA.
- The protein Cas9 (or "CRISPR-associated") is an enzyme that acts like a pair of molecular scissors, capable of cutting strands of DNA.
- The CRISPR/Cas9 genome editing system has two components, Cas9, the endonuclease, and a guide RNA (sgRNA).

Transgenic Development Activities in Horticultural Crops:

Crops	Gene(s)	Functions
A. Biotic stress		
1. Fungi		
Tomato and brinjal	Chitinase, glucanase, thaumatin	Create fungal resistant plant
Tomato	OXDC	
2. Virus		
Banana	BBTV, BBr, MV coat protein gene	Virus resistance
Citrus	CTV coat protein	Virus resistance
Papaya	PRSV coat protein	Virus resistance
Watermelon	WMV coat protein	Virus resistance
Potato	Coat protein	Development of potato virus Y (PVY)
Tomato	Replicase gene	Tomato leaf curl virus (TLCV) resistance
3. Insects		
Tomato	Cry 1Ab	Fruit borer resistant
Brinjal	Cry 1Ab	Resistant shoot and fruit borer
Cauliflower	Cry 1Ab	Diamond back moth resistant
Cabbage	Cry 1Hc/Cry 9C	Resistant lepidopteron insect
Potato	*Bt* Cry 1Ab	Resistant to potato tuber moth
B. Abiotic stress		
Potato	Osmotin	Development of water stress tolerant
C. Post harvest shelf life and quality		
Banana, pineapple	*ACC* synthase	Delayed ripening
Mango, apple	*ACC* synthase and ACC oxidase	Delayed ripening
Strawberry	Pectate lyase	Improved fruit quality
Tomato	*ACC* synthase	Controlling fruit ripening
Tomato	Deoxyhypusine synthase (DHS)	Delayed post harvest softening
Tomato	A-galactosidase-4 (TBG-4)	Improved fruit quality
Tomato	Phytoene desaturase	Increasing carotenoid content

Tomato	Geraniol synthase	Modified flavour and aroma
Strawberry, cucumber, navel oranges, clementines, watermelon	DefH9-iaaM	Parthenocarpy
Melons	*ACC* oxidase, SAM hydrolase	Reduced ethylene production
Potato	*AmA1*	Development of protein rich potato
Cauliflower	*Bar, Barnase, Barstar*	Superior hybrid cultivars
Banana	*Hepatitis B* surface antigen	Pharmaceutical production
Tomato	*Ctx-B* and *Tcp* antigens of *Vibrio cholerae*	Edible vaccine development
Muskmelon	Rabies flycoprotein genes	Edible vaccine development
Parthenocarpy		
Tomato	Rol B gene	Parthenocarpic fruits
Brinjal	Iaah gene	Parthenocarpic fruits

Transgenic varieties in Horticultural Crops:

Crop	Trait	Product name	Year	Organization
Tomato	Shelf life	Flavr Savr	1994	Calgene
	Shelf life	Endless Summer	1995	DNA plant tech
Potato	Bt gene (Resistance to Colorado potato beetle)	New Leaf	1995	Monsanto Co.
	Resistance Bt gene & Potato leaf roll virus (PLRV)	New Leaf Plus	1998	Monsanto Co.
	Bt gene	Maximize	1995	CIBA-GEIGY
	Resistant to viruses	Freedom II	1995	Ashgrow Seeds
	Resistant to Colorado beetle	Elizabeth	2010	Monsanto
Papaya	Resistant to papaya ring spot virus (PSRV)	Rainbow, Sunup	1998	-

Molecular targets for Modifying Flower Colour:

Crops	Flower trait	Target gene
Petunia hybrdia	White → Red	Mutant maize gene
	Purple →White	Chalcone synthase
	White → Pale yellow	Flavonoid biosynthesis
	White →Pink	Flavonol synthesis and DHFR gene
	Red →Deep purple	F3'5'H gene
Rose	Red → Pink/light red/magenta red	Anthocyanin biosynthesis
	Red →Blue	Delphinidin accumulation
Carnation	White → Mauve	Flavonol synthesis
	Violet orange → Cream	F3H gene
Gerbera	Red → Pink/cream	Chalcone synthase gene
Chrysanthemum	Pink →White	Flavonol synthesis
Torentia	Blue →White	Anthocyanin biosynthesis
	Blue →Red	Cytochrome P450 gene

Important genes regulating Flower Shelf Life:

Gene(s)	Function
ACC synthase and oxidase	Inhibition causes reduced ethylene production
ACC deaminase	Over expression causes reduced ethylene production
ETR-1	Expression of a defective gene cause reduced ethylene production
ERS	Expression of a mutated gene causes reduced ethylene production

Novel Plant Traits Engineered through RNAi:

Trait	Target gene	Crops	Application
Enhanced nutrient content	Lyc	Tomato	Increased concentration of lycopene
	DET 1	Tomato	Higher flavonoids and β-carotene content
	SBEII	Sweet potato	Increased levels of amylase for digestive health
Reduced alkaloid content	CaMXMT1	Coffee	Decaffeinated coffee
Reduced production of lachrymatory factor synthase	Lachrymatory factor synthase	Onion	"Tearless" onion
Ethylene early ripening	LeETR4	Tomato	Early ripening tomato

Important Genes Regulating Plant Morphology and Development:

Gene(s)	Function
Clavata, Wuschel	Establishment and maintenance of shoot apical meristem
GA insensitive (*gai*)	Stem elongation and plant height
Brassinosteroid gene (*BRI 1*)	Plant height (Dwarfing)
MAX	More axillary branching
Lazy, TAC 1	Branching angle of tillers
Phtochrome	Shading response and harvest index
Rol C	*Agrobacterium* gene regulating plant branching and architecture
IPT, SAG 1	Cytokinin genes regulating senescence

Important Genes Regulating Flower and Inflorescence Development:

Gene(s)	Function
Agamous	Regulator of determinate floral development
Apetala	Key regulator of ABC model of flower development
Terminal flower	Development of continuous inflorescence development
Leafy	Floral meristem identity
Clavata 1, 2 and 3	Regulator of meristem maintenance
Wuschel	Regulation or meristem initiation

Chapter - 3

A. Basic Pomology

- **Planning and layout of orchard**
  - System of planting
  - Training system
  - Pruning system
  - Special pruning techniques in fruit crops
- **Propagation of fruit crops**
  - Sexual propagation
  - Asexual propagation
  - Use of rootstocks in fruit crops
  - Graft incompatibility in fruit crops
- **High density planting (HDP) in fruit crops**
  - Strategies for HDP in fruit crops
  - Use of Growth Regulators in Fruit Crops

- Study of fruit crops: Pomology
- Pomology word derived from *Greek* word: ; *logy*: study
- Father of systematic pomology: De Candolle
- Leading top three fruit producing countries in the world
  1. China (20.9%)
  2. India (13.6%)
  3. Brazil

Planning and layout of orchard:

- Every 3rd tree in every 3rd row should be planted pollinator tree in self-incompatible varieties for successful fruit production
- Evergreen trees should be planted in the front of the orchard and deciduous one behind
- Contour trenching used when slope about 30-40%
- Wind break has its maximum effectiveness for a distance about 4 times its height
- Total orchard area under roads, buildings, paths, tube wells and channels should occupy only 10%
- Suitable plants for fencing: *Agave, Pithecelobium dulce, Thevetia peruviana*
- Suitable hedge plants: *Duranta plumieri, Lantana camera, Tecoma stans, Prosopis juliflora, Opuntia sp. Clerodendron inerme, Inga dulcis*
- Trees suitable for wind break: *Casuarina equisetifolia, Grevillea robusta, Eucalyptus globules, Polyalthia longifolia, Azadirachta indica, Pterospermum acerifolium, Syzygium sp. Carissa carandas*

System of planting:

a) Vertical row planting pattern:

a) Square system
b) Rectangular system
c) Cluster system

1. Square system:

- Simplest and ubiquitous system of planting
- Most commonly followed system (easy layout)

2. Rectangular system:

- Used in high density planting (HDP) e.g. Mango, Aonla
- Easy cultural operation and easy mechanical operation

Cluster system accommodates nearly twice the population of square system

b) Alternate row planting pattern:

a) Hexagonal system
b) Quincunx system
c) Triangular
d) Contour system

Hexagonal system or equilateral triangle or septule system:

- Accommodates 15% more no. of plants than square system
- Very difficult to layout

Quincunx system or diagonal system:

- Accommodates1.5 -2 times double the number of plants (89%) more than square system
- Filler plants are generally used in quincunx system
- This system accommodates 10% more plants than the square system
- Suitable filler plants: Guava, Kinnow, Phalsa, Plum, Peach, Papaya, Banana, Pomegranate
- Quincunx system is commercially practised where spacing >10m spacing

Triangular system:

- Based on the principle of isolateral triangle
- Accommodates 11% lesser no of plants than square system
- Mostly used for high density planting (HDP)
- Problem in triangular system: Intercultural operation

Contour system

- Commonly used in hilly regions and undulated topography (slope exceeds 10%)
- Double hedge row contour planting system accommodates 22% higher plants than the single hedge row contour planting
- Main advantage: reduce the soil erosion and conserve the soil moisture

Other systems:

- Terrace system: Extension of contour system
- Double hedge contour planting system accommodates 22% higher than single hedge system
- Hedge row planting system is commercially followed in mechanized fruit cultivation e.g. Apple and Pineapple

Training system:

- Training is a new practice in which tree growth is directed into a desired shape and form
- It includes tying, staking or supporting young plants
- Main purpose: Shaping of young fruit trees

Methods of training systems:

- Open center system is also known as vase shaped system

- Central leader system is also known as closed centered one
- Modified leader system: Most acceptable for commercial fruit cultivation
  - Intermediate between the open and central leaders system

Other systems of training:

a) Bower system is also known as pandal or arbour or pergola system-Commonly practised in grapes
b) Telephone system is also known as overhead trellis system
c) Cordons are single stemmed tree system
d) Cordon system is mainly used in gardens as a catalogue of varieties
e) Commercial planting of apples and pears has been successfully done as primitive espalier system

Commercial training systems in fruit crops

Training systems	Examples
Central leader	Walnut, pecan nut, apple
Open center or vase system	Peach, Japanese plum, nectarine
Modified leader	European plum, sweet cherry, pear
Bower system	Grapes
Espalier system	Apple, pear
Cordons	Peach
Single stem system	Citrus, fig, annona
Multiple stem system	Pomegranate
Two arm kniffin system	Passion fruit

Pruning system:

- Pruning is the removal of a portion of a tree to correct or maintain tree structure
- Main objectives:
  - Regulation of shape and growth of tree
  - Enhance the production and quality of fruits
- Pruning is done into 2 ways

1. Thinning out: Removal of undesirable shoots or branches without leaving any stub
   - Encourage the tree growth *e.g.* Mango, loquat, quince, olive

2. Heading back: Removal of terminal portion of the shoots, branches or limb leaving its portion
   - Reduce the tree size by topping and hedging

- **Skirting:** Removal of low hanging branches *e.g.* Mango
- Tip pruning: The young vegetative flushes are cut back to mature wood just prior to flowering e.g. Mango
- Containment pruning is commonly used in HDP of temperate fruit crops

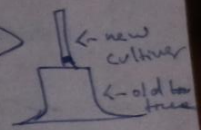
Intensity of pruning	Examples
Light pruning	Guava, Kinnow mandarin, litchi
Slightly severe pruning	Apple
Heavy/severe pruning	Phalsa, ber, mulberry

Special pruning techniques in fruit crops

Special Techniques	Purpose	Examples
Root pruning: Removal of roots 40 cm away from the base of the plant	To make dwarf, to induce flowering , fruitfulness and determining the flowering time	Mandarin
Ringing: Removal of complete ring of bark from a branch or a trunk	To increase fruit bud formation	Mango, Grapes
Dehorning: To removal of overcrowding and intermingling of branches	To induce flowering	Mango (Vidharbha Region of Maharashtra)
Notching: Partial ringing of a branches above a dormant lateral bud	To induce the fruiting branches & increase the bearing area of the plant	Poona Fig (Pune Region of Maharashtra)
Nicking: Partial ringing of a branches below a dormant bud	To increase the flowering shoots To induce spurs from buds	Apple, Poona Fig (Pune Region of Maharashtra)
Smudging: Practice of smoking under the trees	To induce the off season flowering	Mango (Philippines)

Girdling => Removal of xylem, Phloem tissue & cambial tissue
Ringing - only Phloem & cambial tissue is removed.

Bending: Bending of branches or shoots	To increase the lateral branches and fruit production	Guava (Allahabad Region in UP, Deccan region)
Thinning: Removal of part of flower bud or small fruits from a heavy crop	To increase the fruit size To reduce the alternate bearing tendency	Grapes, Peach, Plum, Quince
Girdling: Removal of 2-3 mm white strip of barks around the stem	To increase the berry size	Grapes
Leaf pruning: Removal of old and senescence leaves	-	Date palm
Top working or top grafting or top budding: changing the established plants, trees, shrubs or vines with a desirable cultivars	-	Mango, Apple



PROPAGATION OF FRUIT CROPS

Sexual Propagation/Amphimixis

- ★ **Definition:** Multiplication plants through seeds
- ★ Fruits commercially propagated by seeds: Papaya, Phalsa, Jamun and Mangosteen
- ★ Epigenous germination: Mango, Jackfruit, Tamarind, Cashewnut
- ★ Hypogeal germination: Peach

Development fruit and seed

Ovary	Fruits
Ovule	Seeds
Integuments	Tests- Seed coat
Nucleus	Perisperm
2 Polar nuclei + sperm nucleus	Endosperm (triploid, 3n)
Egg nucleus + sperm nucleus	Zygote-Embryo (diploid, 2n)

Seed dormancy:

- It is a physical or physiological condition of a viable seed which prevents germi... in the presence of favourable conditions for germination

- Juvenility starts after germination and is the stage during which the plant undergoes vegetative growth without any reproductive activities

Type of dormancy:

1. Exogenous dormancy: Due to hard seed coat: Ber, guava, walnut
2. Endogenous dormancy: Due to presence of chemical inhibitors (Abscisic acid) e.g. temperate fruit crops, strawberry, grapes

Breaking of seed dormancy:

A. **Scarification:** physical or chemical abrasion of seed coat

i. Mechanical scarification: Ber (H_2SO_4, 6 minutes), aonla, Peach, Walnut

ii. Hot water scarification: Guava @ 77 to 100°C => Soak in cool water for 12-14 hours

iii. Acid scarification:

- Sulphuric acid treatment: Guava@ 3 minutes, Ber @ 5-6 hours
- Nitric acid (0.25%) or hydrogen peroxide treatment: Strawberry

B. **Stratification:**

- The term moist chilling synonym to stratification
- Chilling temperature: 0 to 10°C

Cold stratification:

- Dormant seeds are exposed to abundant moisture, ample O_2 and relatively cold temperature
- Apple, cherry, pear, peach- Seeds are placed in sand box @ 1-5°C and duration of 1 to 5 months
- Placing the seeds in running water for leaching of inhibitors:
  - e.g. Fresh seeds of grapes and strawberry: keeping them up to 7-12 days

C. **Other methods**

I. **Chemical treatments:**

- Potassium nitrate (KNO_3) @ 0.1 to 0.2% e.g. Guava, Ber
- Thiourea @ 0.5 to 3%: Peach, Plum

II. **Use of hormones:**

- Apple, cherry, peach, strawberry and hazelnut: GA_3 @ 100-500 ppm
- Guava and strawberry: Ethrel @ 5000 ppm
- Apple and peach: Benzyl adenine (BA) @ 10-20 ppm

Seed storage:

- **Orthodox seeds**: Desiccation tolerance during development and may be stored in the dry state for predictable periods under defined conditions
- **Recalcitrant seeds** do not survive drying to any large degree and are thus not amenable to long term storage

Classification of fruit seeds based on storage behaviour

Orthodox seeds	Recalcitrant seeds
Apple, grapes, ber, peach, plum, phalsa, pomegranate, passion fruit, custard apple, date palm, fig, guava	Mango, mangosteen, citrus, jackfruit, loquat, litchi, rambutan, avocado, barbados cherry, carambola, durian, bread fruit, rubber, cocoa, oil palm

Cryopreservation:

- Storage of seed material in liquid nitrogen N_2 @ -196°C and liquid carbon dioxide -43°C
- Most commonly used cryoprotecatants: Glycerol and Dimethyl sulphoxide (DMSO)

ASEXUAL PROPAGATION

Asexual propagation/vegetative propagation/clonal propagation:

Definition: Multiplication or perpetuation of any plant from any vegetative parts of plant

- Basic process of normal vegetative growth: Mitosis
- Asexual or vegetatively propagated fruit plants are true to type
- Clone: Genetically uniform materials derived from single individual
- For most of the cuttings, day air (21 to 27°C) and night temperature (15°C) are satisfactory for rooting
- Most common and effective rooting growth regulator for cuttings: Indole Butyric Acid (IBA)

Parthenogenesis:

- Fruits develop parthenocarpically still they produce viable seeds e.g. Mango, strawberry
- Produce genetically uniform seedlings

Polyembryony:

- **Definition:** Formation of multiple embryos in a single seeds (More than 1 seedling)
- Term coined by Brau (1859)

- 1st discovered by Leeuwenhoek (1979) in *Citrus aurantium*

★ Polyembryonic fruit plants: Mango (Olour, Kurukkan, Chandrakaran, Vellaicolumban), Citrus, Jamum

Advantages:

+ Production of superior clones, free from virus, source of haploids

Type of polyembryony:

1. Nucellar polyembryony/adventives polyembryony:

   e.g. Citrus (More no. of seedlings/seed: *Citrus unshiu* (40 seedlings)), Mango

2. Cleavage polyembryony: Coconut

Apomixis:

★ Apomixis: Asexual reproduction through seeds

- Term coined by Hacke (1893)
- Discovered by Winkler (1908)

★ Apomictic seedlings are true to type and free from viruses

★ Apomixis apple species: *Malus sikkimensis, M. hupehensis, M. sargenti, M. toringoides*

★ Apomictic species of apples are commercially propagated by seed

★ Seed borne viruses: Psorosis in citrus, mosaic in peach, cherry and almond

Type of apomixis:

- Recurrent apomixis: *Malus spp., Rubus spp.*
- Non-recurrent apomixis: *Solanum nigrum, Lilium spp.*
- Nucellar embryony or adventitious embryony: *Citrus spp.*
- Vegetative apomixis: Garlic, Agave, *Dioscorea bulbifera*

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Genetic variation in asexually propagated crops

Mutation

★ Sudden and heritable changes in the DNA

- Most of fruit crops highly heterozygous in nature
- Mutation highly useful for highly heterozygous trees
- Spontaneous mutation grapes varieties: Sonaka, Saritha

Chimera:

★ In vegetatively propagated crops, mutations expressed in the form of chimeras

★ Definition: A plant or plant parts composed of genetically different layers or tissue in an individual.

★ It occurs in apical buds, axillary buds and adventitious buds

★ Cheimeras or sports term coined by Hans Winkler, German botanist (1907)

★ Chimeras, which are formed from a conglomeration cells that originated from separate zygotes

★ Genetic mosaics, which initiate from a single zygote and are subsequently induced or mutated into a heterogenomic state

★ Somatic mutation rates 1.6×10^{-10} mutations occur per base per cell division.

★ Variegated mosaics: Variation in leaves *e.g.* Coleus, crotons, bougainvillea

★ Sectorial chimera: changes occurs in part of inner or outer layer. Unstable type

★ Periclinal chimera: changes in entire inner or outer layer. More stable form (Vegetative propagation)

★ Mericlinal chimera: mutation occurs in one layer and side of apex region. Not stable

★ Chimeras are successfully utilized in ornamental crops

★ Bud sport apple varieties: *e.g.* Starking Delicious, Richa Red

Cuttings:

★ Vegetative material (small pieces) obtained from any of the three primary plant organs *e.g* stem, leaf, or root

★ Most commonly used asexual propagation method in the horticulture propagation

- Juvenility: The physiological age of the cutting significantly affects its rooting success

★ IBA rooting hormone generally used for cuttings to induce roots

★ IBA available at dust forms: Seradix A and Seradix A

I. Stem cuttings:

a. Hardwood stem cuttings

+ Cutting derived from mature or woody stem materials e.g. Fig, Olive, Grapes, Pear
+ Deciduous hardwood cuttings mostly done from leafless plants in late winter or early

  Spring

b. Semi-hard wood stem cuttings:

- Cuttings are made from the spring growth of trees and shrubs, more mature than softwood

- Most widely used in evergreen fruit plants
  - e.g. Lemon, Jack fruit, Mango, Guava
- ★ Bottom heat technique: Novel technique used for rooting of semi-hardwood cuttings
- ★ Bottom heat technique (BHT) temperature: 30±2°C *e.g.* Mango, Guava, Aonla
- ★ Bottom heat in cutting beds warms the soil to induce quicker rooting
- ★ The bottom heat is usually about 6°C higher than the air temperature, which should be maintained

18 to 27°C

ii. Root cuttings: e.g. Blackberry and raspberry

Inducing rooting in hard to root stem cuttings

- Soak method: dipping of cuttings 10-100 ppm for 12-24 hours before planting
- Quick tip method: dipping of cuttings 1000-5000 ppm for 5 seconds before planting

Layering methods:

- ★ Basic of rooting in layering due to effect of : Etiolation
- ★ Etiolation means growing particular plant parts in darkness (Branch is covered in the soil)
- ★ Darkness promotes etiolation in plants
- ★ Ideal period for air layering: February-March and June-July
- ★ Commonly used medium in air layering: Sphagnum moss

Ground layering:

a) Simple layering: (one year old branches mostly used) e.g. Guava

b) Compound or serpentine layering: Modification of simple layering. Best suited to plants that have a pendulous growth habit and flexible branches

e.g. American grapes, Muscadine (*Vitis rotundifolia*)

c) Trench layering or etiolation methods: Cherry, plums and apple rootstocks

d) Tip layering: (current season shoot) Blackberry, raspberry and dewberries

e) Mound layering or Stooling- Modification of etiolation method of layering

e.g. Rootstocks of apple and pear

f) Air layering/gootee/marcottage: Litchi, Guava, Jackfruit

- Ideal time for air layering: February- March and June-July
- Lanolin paste commonly used in air layering and stooling

Grafting/Graftage:

★ **Grafting** is an asexual propagation method in which parts of two different plants are joined so that they continue their growth as one plant

Intermediate stock / Interstock → Overcome graft incompatibility.

- ★ Rootstock (or simply *stock*), bottom part, which is in contact with the soil
- ★ Rootstock or under stock: Low portion of graft (Develops the own root system)
- ★ Scion: The plant part that is the top part of a graft and grows to become the desired shoot
- ★ Scion: Detached shoot with buds *i.e.* united to the rootstock
- ★ Wood consist of secondary xylem and pith
- ★ Bark: Periderm, cortex, phloem and vascular cambium
- ★ Healing of graft region:
  - Production of callus (undifferentiated cells) by mitosis and occurs in the cambium region of the two parts
  - Vascular transport restored between the scion and stock
  - Alignment of xylem for xylem and phloem for phloem regions
  - Healing bridges between stock and scion due to callus formation
- ★ Callus formation starts from 1-7 days after grafting
- ★ Optimum temperature for callus formation for grafting: 27-30°C
- ★ Callus mostly develop from scion due to base movement of auxin and carbohydrate
- ★ Interstock: Section of stem inserted between a graft union or between scion and rootstock
- ★ Interstock use: Overcome incompatibility
- ★ Intravarietal grafting: Elberta peach on Elberta peach
- ★ Interaclonal grafting: 100% success compared to other grafting
- ★ Intervarietal grafting: Mango
- ★ Interspecific grafting: Japanese plum is grafted commercially on peach
- ★ Intergeneric grafting: *Citrus* spp. on trifoliate orange, Sathgudi on wood apple, Sapota on Pala

Renovation and rejuvenation grafting:

- ✦ Buttress grafting
- ✦ Bridge grafting: both ends of the scion to be grafted
- ✦ Generally rejuvenation grafting practised in mango, guava, Amla

Attached method of grafting:

- ★ Inarching or simple approach grafting or embracing: Mango, Sapota: Extensively practised in Tamil Nadu and Andhra Pradesh
- ★ Approach tongue grafting: Modification of simple inarching: Apple, pear and walnut

★ To rejuvenate old, weak growing, diseased or damaged trees to give a new lease of life, inarching is followed which is known as "adjuvant grafting"

Detached method of grafting:

★ Whip or splice grafting : Apple, pear

★ Tongue grafting: Modified form of whip grafting *e.g.* Apple

★ Side grafting: 2 types: a. Stub grafting b. Side tongue grafting

★ Cleft or wedge grafting: More useful for top working in mango, sapota, fig and Mangosteen

★ Cleft grafting is done in late winter or early spring.

★ Cleft or wedge grafting or top grafting is commonly employed for rejuvenating temperate orchards by "top working"

✦ *e.g.* Walnut, Peacanut, hazelnut

★ Notch grafting or inlaying: Used in humid tropics

★ Softwood grafting or *insitu* grafting:

★ Effective in dry, hot weather or low precipitation areas

e.g. Mango, cashew, avocado and tamarind

★ Epicotyl grafting or stone grafting:

✦ Mango- Rapid multiplication of mango (2 weeks old seedlings) in Konkan region, Maharashtra

★ Veneer grafting:

✦ Most ideal for establishing insitu orchards and top working of older orchards

✦ Mango is commercially propagated by veneer grafting in North India (September-October)

★ Bridge grafting:

✦ A form of repair grafting

✦ Used to saving severe damage of tree trunk

★ Double working:

✦ Bartlett pear on quince dwarfing rootstock by using interstock as "Old Home"

✦ Interstock or intermediate stock is commonly used in double working for overcoming graft incompatibility

★ Top working or top grafting or top budding: *e.g.* Cashewnut, mango

USE OF ROOTSTOCKS IN FRUIT CROPS

S.NO	Fruits	Rootstocks	Specific features
1	Mango	**A. Polyembryony rootstocks** Sabre, Chandrkaran, Bappakai, Olour, Goa, Salem, Pahutan, Kurukan, Nileswar dwarf, Ambalvi, Muvandan, Nekkare, Starch, Peach, Kitchner	Kurrukan – Salt resistant ▪ Muvandan, Olour- Vigorous Vellaikolamban- Dwarfing rootstock for Alphonso and Dasheri ▪ 13/1 (Israel) – Tolerant to calcareous soils ▪ Bappakai- Best for Neelum variety ▪ Creeping, Rumani: Dwarfing
		B. Monoembryonic rootstocks Rumani, Dashehari	Tolerant high salinity Dwarfing effect
2.	Guava	Pusa Srijan (aneuploid Tetrasomic, 2n+2)	Dwarf rootstock for Allahabad Safeda
		P. friedrichsthalianum	Resistant wilt and nematode
		P.molle	Resistant to guava wilt
		P.pumilum	Highly dwarf
3	Sapota	Rayan or Khirni (*Manilkara hexandra*)	Commercial rootstock in india
		Chrysophyllum lanceolatum	Wider soil adaptability
4	Jamun	*Syzygium densiflorum*	Resistant to termite
5	Custard apple	Pond apple: *Annona glomerata* *Annona globra*	Tolerant to flood condition Dwarf rootstock
6	Fig	*Ficus glomerata*	Resistant to root knot nematode
7	Ber	*Zizypus nummularia* *Z. rotundifolia*	Dwarf, salt tolerant Tolerant to drought
8	Avocado	Duke-7 **New rootstocks:** Zentmyer, Uzi, Steddom	Tolerant to phytophthora root rot Tolerant to phytophthora root rot

9	Citrus	Sour orange (*C. aurantum*)	Tolerant to xyloporosis, exocortis and gummosis, standard rootstock for phytophthora root rot
		Rough lemon (*C. jambhiri*)	Highest rank citrus rootstock in india
			Tolerant to tristeza, xyloporosis, exocortis and gummosis, suitable for deep sandy soils
		Trifoliate orange	Cold hardy, tolerant to phytophthora, tristeza, RKN and dwarfing
		Flying Dragon trifoliate orange (*C. trifoliata var. monstrosa*)	Potential dwarfing rootstock (HDP)
			Resistant to tristeza virus
			Tolerant to Tristeza, xyloporosis, exocortis and gummosis
		Troyer' citrange	Most promising rootstock for Nagpur mandarin & Kinnow mandarin in india.
			Suitable dwarfing rootstock for Kinnow in india
		Karna Katta, Jatti Khatti	Suitable semi-vigorous rootstock for Kinnow in india
		Gajanimma	Suitable for acid lime/lemon
		Sohsarkar	Suitable vigorous rootstock for Kinnow in india
		Rangpur lime	Hardy rootstock
			Promising rootstock for Nagpur mandarin and sweet orange (central and south india)
			Tolerant to tristeza, salt, soil toxicity
			Resistant to drought, high vigorous
		Rough lemon (*C. Jambhiri*)	Suitable for Khasi mandarin
			Suitable rootstocks for sweet orange in india. Resistant to tristeza, xyloporosis, exocortis Phytophthora and greening
		C. macrophylla	Resistant to tristeza virus
		C. unshiu	Tolerant freezing condition
		Citron, Kumquat	Highly resistant to citrus canker

		Cleopatra mandarin	Salt tolerant, Suitable for sweet orange (North east India)
		Volkamer lemon (*C. volkameriana*)	Suitable for navel orange, Valencia orange and grape fruit
		Severinia buxifolia	Resistant to salt
10.	Grapes	*Vitis berliendieri, V. riparia V. champini*	Tolerant to soil salinity
		Salt creek (*V. champini*)	Resistant to salt and nematodes
		Dogridge (*V. champini*)	Popular resistant rootstock for Phylloxera, nematode, drought and salinity prone areas
		St. George (cv. *V. rupestris*)	Salt tolerant
		Riparia Gloire (cv. *V. riparia*),	Phylloxera resistant rootstock
		Ramsey (*V. champini*)	Preferred rootstock for warmer regions
11	Apple	**A. Seedling rootstock**	Crab apple
		B. Clonal rootstocks	
		M9	Dwarf, suitable for HDP
		M27 (M13×M9)	Ultra dwarf, suitable for HDP
		MM104, MM106	Resistant to apple wooly aphids
		MM111, MM104	Resistant to drought
		MM111	Vigorous
		G.41	New dwarf rootstock (HDP), high resistant to fire blight a[illegible] phytophthor
		G.16	New fully dwarf root[illegible] resistant fire blight. (alternative to M9)
		G.935	Winter hardy, highly resistant to blight and phytophthora (alternativ M26)
		Northern spy	Resistant to apple w[illegible]ds

12	Pear	A. Seedling rootstock	Kainth (*P. pashia*) commercially used in india
		B. Clonal rootstocks	
		Quince C	Ultra dwarf, suitable for HDP
		Quince A	Vigorous, preferable rootstock
		OH x F-333 (OHF)	Semi dwarf
		D-4 (*P.calleryana*)	Most vigorous rootstock
		Old Home, Farmindale	Resistant to fire blight
		OHF series (Oldhome × Farmindale)	Resistant to fire blight
13	Plum	A. Seedling rootstock	Wild apricot
		B. Clonal rootstocks	
		Myrobalan B	Resistant to cold. Collar rot and nematodes
		Mariana	Resistant to nematode
		St. Julien (*Prunus insititia*)	Most versatile rootstock for plums
		Pixy (Selection from St. Julien)	Ultra dwarf rootstock
		St. Julien A	Vigorous
14	Peach	Nemaguard, Nemared, Flordaguard, Guardian	Resistant to nematode (RKN)
		GF 677 (Natural peach-almond hybrid), Cadaman, Barrier 1	Tolerant to calcareous soils
		Sharpe	Tolerant to *Armillaria* fungus
		Julior, Penta, Tetra	Tolerant to water logged soil
		Rubira, Tetra	Semi-dwarfing
		Titan Hybrid	Highly vigorous, root-knot nematode resistance, tolerant of calcareous soil
15	Cherry	Gisela	Cold hardy
		Mazzard (*P. avium*)	Dwarf, commercial rootstock for sweet cherry
		Colt	Semi dwarf resistance to Phytophthora root rot, bacterial canker

		F 12/1	Tolerant to bacterial canker, recommended for H.P
		Mahaleb (*P. mehaleb*)	Most drought-tolerant, suited to deep, well-drained loams
16	Almond	Nemaguard Peach - almond hybrids Titan, Hansen Complex hybrids Viking, Altas	Most widely used rootstock
17	Apricot	Wild apricot	Commercially used in india
18	Walnut	Paradox (*J. hindsi* × *J. nigra*)	Vigorous , moderately resistant to phytophthora
		J. hindsii	Tolerant to waterlogged soils

GRAFT INCOMPATIBILITY IN FRUIT CROPS

Graft incompatibility:

- The inability or failure of rootstock and scion grafted togetner to produce a successful graft union

Types of graft incompatibility:

1. **Partial incompatibility:** e.g. Mandarin grafted on trifoliate orange rootstock
2. **Localized incompatibility:**
   - Pear and quince graft (Need pear interstock Old Home for combining two different genera)
   - Apricot and plum graft
   - Localized incompatibility symptoms: Bark cell necrosis, wood discontinuity
3. **Translocated incompatibility:** Peach scion (Hales early) grafted in plum (Myrobalan B) rootstock
   - Symptoms: Phloem degeneration
4. **Delayed incompatibility:**
   - Black line formation in tree *e.g* Walnut
   - Walnut grafted with *Juglans hindsii* or paradox rootstock
   - Sapota on *Bassia latifolia* (Illupai)

Budding:

- ★ A form of grafting in which the scion consists of a single vegetative bud from s
- ★ Budding is a relatively easier procedure than grafting

★ Major difference between budding and grafting is that budding uses a single bud the scion, whereas grafting uses a piece of plant material consisting of several buds

★ Budding may be described as psuedografting or bud grafting

- Shield budding or T budding (Thin bark): Sweet oranges, rose, plum, peach
- T budding: It is the most widely or commonly used budding method in plant propagation.
- Inverted 'T' budding: Widely used in high rainfall areas *e.g.* Chestnut
- Patch budding: Plants that are difficult to bud by the T-method because of a thick bark trees

  e.g. Citrus, mango, rubber, annona, aonla, jackfruit, jamun
- Ring or annular budding: *e.g.* Aonla
- Chip budding: cut that includes a larger chip of wood, more wood than bark

  e.g. Grapes (For nematode and pholloxera tolerant rootstock), apple and pear
- Spring budding (March to April): *e.g.* Citrus
- June budding (June): *e.g.* Peach, plum, apricot, cherry, ber, aonla
- Fall budding (Mid-June to Mid-September): Mango, guava, ber, bael, jackfruit, wal chestnut

Specialized plant parts:

A. Rhizome (Modified stem): banana

B. Sucker (Shoot): Pineapple, banana

C. Crown or Split: Strawberry

D. Runners (Specialized stem): Strawberry

E. Offset or Offshoot (Lateral shoot or branch): Date palm, pineapple

F. Slips: Best planting material for pineapple

High density planting (HDP) in fruit crops

★ High Density Planting is 1st established in Apple at England, 1960

★ Low density: traditional planting method with wider spacing

★ Moderate or medium HDP: 250-500 plants/ha

★ HDP: 500-1000 plants/ha

★ Ultra high density planting: > 1000 plants/ha,, e.g. Apple, Mango

★ UHDP for mango: Alphonso 3 m × 2 m, 1,666 plants/ha (with proper canopy management)

★ UHDP for apple: 3 m × 3 m, 1,111 plants/ha (with proper canopy management)

★ Canopy management: light is a critical factor for growth and development

★ Canopy management: Manipulation of tree to optimize the production of quality fruits

★ **Meadow orchard or super high density planting**

- ★ 10,000 plants/ha
- ★ Modern method of fruit cultivation using small or dwarf tree with modified canopy
- ★ Main objective: Mechanization of all orchard activities
- ★ Meadow orchard system is originated from Israel
- ★ Meadow orchard system originally developed by J.P. Hudson (1971) in apple

★ Amenable fruit crop for Meadow orchard: Peach (5 m × 1 m, 2000 plants/ha, 2 m × 1 m 5000 plants/ha)

★ In India commercially adopted to guava (1.0 × 2.0 m, 5000 plants/ha) developed by Central Institute for Subtropical Horticulture, Lucknow

★ Training method followed in HDP orchard: Central leader system

★ Key to success of HDP: Control of tree size

★ Suitable apple types for HDP: Spur

Strategies for HDP in fruit crops

1. Genetically dwarf varieties:

S.No	Fruit crops	Varieties	Spacing (m)	No.of plants/ha	System of planting
1	Mango	Amrapali	2.5 × 2.5	1600	Triangular system
		Arka Aruna	-		
2	Banana	Robusta	1.5 × 1.5	4400	Square system
		Dwarf Cavendish	1.5 × 1.5	4400	Square system
3	Papaya	Pusa Nanha	1.2 × 1.2	6400	
4	Sapota	PKM-3			
6	Peach	Red Heaven, Candor			
7	Cherry	Meteor			

2. Manipulation of plant spacing:

S.No.	Fruits	Varieties	Spacing	Total no plants/ha	System of planting	Specific features
1	Banana	Robusta, Grand Naine, Poovan	1.2 × 1.2 × 2.0 m	5,200	Paired row	-
		Rasthali and Ney Poovan	1.5 × 1.5 × 2.0 m	3,800	Paired row	-
2	Pine apple	-	25 × 60 × 90 cm (plant-row-trench)	53,300	-	Hot and humid tropical areas
		-	22.5 × 60 × 75 cm	63,400	Double row	Sub-tropical and mild humid areas
		-	25 × 60 × 90 cm	43,500	-	North eastern states
3	Guava	Allahabad Safeda	1.0 × 2.0 m	5,000	-	-
4	Mango	Mallika	3.0 × 2.5 m	1,333	-	-

3. Utilization of dwarf rootstocks:

S.No	Fruit crop	Dwarfing rootstock	Special features
1	Guava	Pusa Srijan	Aneuploid rootstock (Tetrasomic)
			Potential dwarfing effect on Allahabad Safeda
2		*P. pumilum*	-
3	Mango	Vellaikolamban	Suitable for Alphonso and Dasheri
		Olour	Suitable for Langra and Himsagar
4	Citrus	Troyer citrange	Suitable for Kinnow mandarin
		Trifoliate orange cv. Flying Dragon	Standard rootstock for sweet orange
5	Ber	*Zizypus nummularia*	-
6	Avocado	Mt4	-
7	Apple	M9	Precocious , productive rootstock
		M27, P-22, G-65	Ultra dwarf
		G.16	Alternative to M9
		G.935	Alternative to M27
8	Pear	EMLA Quince C	Ultra dwarf
		Quince C	
		OH x F51	
9	Plum	Pixy	Ultra dwarf

4. Training and pruning dwarfness:

A. Training:

- ★ Central leader system: Dwarf apple trees
- ★ Removal of apical portions: Mango, guava, litchi

B. Pruning:

- ★ Pruning and hedging: Mango
- ★ Topping and hedging: Guava
- ★ Topping: Aonla
- ★ Common pruning: Grapes, Apple, Guava, Ber, Fig

5. Tree size control

Chemicals used for tree size control:

- ♣ Daminozide, Chloromequat, Paclobutrazol, CCC, B-9, Ancymidal, AMO 1618, Ethephon

1. **Mango**: Reduction in tree height in Alphonso by application of paclobutrazol 10 g/tree during months of Aug–Sept.
2. **Apple**: Reduction rootstock suckers: Ethyl ester form of NAA (Tre-Hold Sprout Inhibitor A-11
3. **Grapes**: Reduction of internode length, shoot growth: CCC 500 ppm

Use of Growth Regulators in Fruit Crops

S. No	Fruits	Growth regulator	Effects	Features
1.	Mango	NAA @ 200 ppm	Reduction of fruit drop	Pea stage
		NAA @ 200 ppm	Reduce the floral malformation	Time of fruit bud differentiation (October-November)
		2,4-D	To control pre-harvest fruit drop	
		P_{333} (Paclobutrazol) 1.25 to 10 g a.i/tree)	Control of vegetative flush during October-November Manipulation of flowering	Alphonso (Post harvest application) Dasheri , Banganapalli
		GA_3	Recurrent flowering	Alphonso
2.	Citrus	2,4-D @ 20 ppm	To control pre-harvest fruit drop	Mandarin & mandarin hybrids
		NAA @100-500 ppm	Fruit thinning	-
		GA_3	Delay fruit senescence	-
3.	Avoc-ado	2,4-D @ 20-25 ppm	Reduction of fruit drop	-
4.	Grapes	GA_3 @ 10-40 ppm	Enlargement of panicle growth	-
		GA_3 @ 10 ppm	Rachis elongation	One month after forward pruning (4-5 leaf stage
		GA_3 @ 30-40 ppm + CPPU @ 2 ppm	Berry elongation	Bajra grain size berry stage
		GA_3 @ 30-40 ppm	Berry length	-
		CCC @ 250-500 ppm	Suppression of vine growth and increase the fruitfulness of buds	After back pruning (5 leaf stage)
		GA_3 @ 50 ppm	Berry thinning	50% bloom stage
		GA_3 30-40 + Cytokinin	Bunch elongation	Bunch dipping at 6-7mm berry size
		4-CPA @ 10 ppm	Increase the pedicel thickness	-
		NAA @ 20-50 ppm	Post-harvest berry drop	-

		Cytokinin (6 BA)	Increase the berry size	After pruning
5.	Banana	2,4-D @ 20 ppm	Removal of seediness	Poovan variety
		Ethrel @ 500 ppm	Accelerate the ripening	-
6.	Guava	IBA @ 3000 ppm	Promotes the roots (100%) in air layering	-
		Urea 10 to 20 %	To avoid rainy season crop (due to production of poor quality fruits)	Spraying at summer season at peak flowering time
		NAA @ 80-100 ppm	To reduce the rainy season fruit yield	-
		NAA 800 ppm + Deblossoming	Maximum yield in winter season	-
		NAD @ 50 ppm	Enhances the high blossom drop	-
7.	Sapota	NAA @ 120 ppm	Increase the fruit set and yield	-
8.	Pine apple	Ethephon @100 ppm	Uniform flowering	All months
		Ethephon combination with (Urea 2% +Ca/Na carbonate 0.04%)	Uniform flowering	March - May season
		NAA @ 10-20 ppm	Flower induction	Less effective
		NAA @ 200-300 ppm	Increase the fruit size	After fruit set
9.	Date palm	Ethephon @ 500-1000 ppm	Enhances the early ripening	To avoid the rainy season
		Ethephon @ 100-400 ppm	Flower or fruit thinning agent	-
10.	Apple	NAA @ 2-10 ppm	Effective thinning agent	-
		NAA+ Sevin	Heavy thinning	-
		NAA @ 10	Prevent the pre-harvest fruit drop	-
11.	Peach	Ethephon @ 100-300 ppm	Fruit thinning	Before pit hardening stage

12.	Plum	NAA @ 25-75 ppm	Fruit thinning	Japanese plum (Santarosa)
		Ethephon @ 10-100 ppm	-	-

★ Bahar treatment: Induction of flowering in desired season

★ To Commercial hormone used for cuttings: IBA

★ To overcome the chilling requirement in temperate fruits: GA_3

★ To induce greater fruit set and mainly used as spray solutions on the trees: NAA @ 25-50 ppm

★ Self-thinning capacity fruits: Mango and Apple

★ Fruit crops flowers thrice in a year: Mandarin and Sweet orange

★ Post set fruit drop is major problem in mango

B. Classification of Fruit Crops

Classification of Fruit Crops:

1. Botanical classification of fruit crops
2. Classification of fruits based on climate
3. Classification of fruits based on woody plants and herbaceous plants
4. Classification of fruits based on photoperiodic response
5. Classification of fruits based on fruit bearing habit
6. Classification of fruits based on position of flower bud and kind of flower bearing shoots
7. Classification of fruits based on flowering habit
8. Classification of fruits based on types of inflorescence
9. Classification of fruits based on the breeding system
10. Classification of fruits based on mode of pollination
11. Classification of fruits based on fruit bud
12. Classification of fruits based on hardiness of skin
13. Classification of fruits based on fruit morphology
14. Classification of fruits based on type of placentation
15. Classification of fruits based on growth pattern
16. Classification of fruits based on tolerance to shade
17. Classification of fruits based on acid tolerant fruit crops
18. Classification of fruits based on relative salt tolerance fruit crops
19. Classification of fruits based on their respiratory behaviour
20. Classification of fruits based on rate of respiration rate
21. Classification of fruits based on rate of ethylene rate
22. Classification of fruit crops based on storage life

Miscellaneous:

1. Derivation of common fruits from various plant tissues
2. Edible portion of fruit crops
3. Nutritive value of fruits
4. Major colour compounds present in fruit crops
5. Aroma compounds responsible for fruits
6. Volatile compounds (Aroma)
7. Aroma is due to esters
8. Bitterness is due to flavonoids and terpenoids
9. Classification of fruits based on their ploidy levels
10. Completed and release genome sequences in fruit crops
11. Promising introduced fruit varieties from exotic source in India

1. Botanical classification of fruit crops:

Family	Common name	Scientific name	Chromo-some No. (2n)	Origin	Fruit type
1. Monocots					
Bromeliaceae	Pineapple	*Ananas comosus*	50, 75, 100	Brazil	Aggregate berries
Musaceae	Banana	*Musa balbisiana*	22, 33, 44	Indo-Burma	Berry
	Plantain	*Musa acuminata*	22, 33, 44	Indo-Malayan	Berry
Arecaceae	Datepalm	*Phoenix dactylifera*	36	West Asia	Drupe
2. Dicots					
Actinidiaceae	Kiwi	*Actinidia deliciosa*	58	China	Berry
Anacardiaceae	Mango	*Mangifera indica*	40	South East Asia	Drupe
	Pistachio nut	*Pistachia vera*	30	Iran/Iraq	Nut
	Indian hog plum	*Spondias pinnata*	-	-	Drupe
	Hog plum	*Spondias cytherea*	-	-	Drupe
Annonaceae	Atemoya	*Annona atemoya*	14	Man-made hybrid	Aggregate berries
	Bullock's heart	*Annona reticulata*	14	-	Aggregate berries
	Cherimoya	*Annona cherimoya*	14	Bolivia	Aggregate berries
	Custard apple	*Annona squamosa*	14	West Indies	Aggregate berries
	Sour sop	*Annona muricata*	14	South America	Aggregate berries
Apocynaceae	Karonda	*Carissa carandas*	22	-	Berry
	Natal plum	*Carissa grandiflora*	22	-	Berry
Bombacaceae	Durian	*Durio zibethinus*	56	Malayan region	Berry

				(Borneo)	
Caricaceae	Papaya	*Carica papaya*	18	Tropical America	Berry
Corylaceae/ Betulaceae	Filbert/Hazelnut	*Corylus avellana*	-	-	Nut
Dilleniaceae	Elephant apple	*Dillenia indica*	-	South East Asia	Fleshy calyx
Ebenaceae	American persimmon	*Diospyros vixgiana*	-	China	Berry
	Persimmon	*Diospyros kaki*	90 (6x)	China	Berry
Ehretiaceae	Lasoda	*Cordiya mixa*	-	-	Berry
Euphorbiaceae	Aonla	*Emblica officinalis*	28	South East Asia	Capsule (Drupe)
	Star gooseberry	*Phyllanthus acidus*	-	Madagascar	Berry
Fagaceae	Chinese chest nut	*Chestua mollissima*	-	-	Nut
	European/ sweet chest nut	*Chestua sativa*	-	-	Nut
Clusiaceae	Mango-steen	*Garcinia mangostana*	28	Malayan Archipelago	Berry
	Malabar tamarind	*Garcinia cambogia*	-	-	Berry
Lauraceae	Avocado	*Persea americana*	24	Central America	Berry
Malphighiacae	Barbados cherry	*Malphigia punicifolia*	40	Trinidad and Tobago	Drupe
Moraceae	Bread fruit	*Artocarpus altilis*	56	Indo-Malayan	Sorosis
	Jack fruit	*Artocarpus heterophylla*	56	India	Sorosis
	Monkey jack	*Artocarpus lakoocha*	56	Western Ghats	Sorosis
	Fig	*Ficus carica*	26	-	Syconus
	Mulberry	*Morus alba*	308	-	Sorosis
Myrtaceae	Guava	*Psidium guajava*	22	Tropical America	Berry

3. Classification of fruit crops based on woody plants and herbaceous plants:

A. Fruits borne on woody plants	
i. Tree fruits	
Deciduous	Pome: Apple, pear, quince
Deciduous	Drupe: Peach, plum, apricot
Evergreen	Tropical: Mango, sapota, guava
Evergreen	Subtropical: Mangosteen, litchi, sweet oranges
ii. Small fruits	
Deciduous	Raspberry, blackberry
Evergreen	West Indian Cherry
B. Fruits borne on herbaceous perennial plants	
Prostrate growth	Strawberry
Upright growth	Banana, pineapple

4. Classification of fruits based on photoperiodic response:

Photoperiodism	Examples
A. Long day plant (LDP)	Passion fruit, apple
B. Short day plant (SDP)	Strawberry, pineapple cv. Smooth Cayenne
C. Day-neutral plant (DNP)	Papaya, guava, banana

5. Classification of fruits based on fruit bearing habit:

A. Terminal bearing habit	
i. Old season growth	Mango, banana, pineapple, litchi
ii. Current season growth	Jackfruit, Loquat, Peacanut
B. Axillary bearing habit	
i. Current season growth	Guava, papaya, orange, passion fruit, coconut
ii. Old season growth	Apple, pear, peach, plum, custard apple
C. Mixed bearing habit	Pomegranate, citrus, carambola

6. Classification of fruits based on position of flower bud and kind of flower bearing shoots

	Fruit buds borne	Inflorescence	Examples
Group 1	Terminal	without leaves	Mango
Group 2	Terminal	with leafy shoots	Apple, pear
Group 3	Terminal	with leafy shoots in the leaf axils	Guava
Group 4	Lateral	without leaves	Citrus, papaya, coffee, coconut
Group 5	Lateral	with leafy shoots	Grapes
Group 6	Lateral	with leafy shoots in the leaf axils	Fig, avocado
Group 7	Both terminal and lateral	-	Walnut
Group 8	Adventitious in old trunk	-	Jack, cocoa, Indian star goose berry

7. Classification of fruits on the basis of flowering habit (Kozlowski, 1971)

Flowering habit	Examples
Ever flowering	Fig, papaya
Non-seasonal flowering	Mango
Gregarious flowering	Quince
Seasonal flowering	Guava, litchi, apple, pear

8. Classification of fruits based on types of inflorescence:

Types	Fruit crops
A. Raceme	
a. Solitary	Guava, peach, quince, apricot, almond, trifoliate orange
b. Raceme	Blackberry, gooseberry, raspberry
c. Catkins	Peacanut, walnut, chestnut, mulberry
d. Corymbose	Pear
B. Cymose	
i. Panicle	Grapes, litchi, mango, loquat, pistachio n

ii. Solitary	Papaya, sapota, citrus, phalsa, persimmon, strawberry
iii. Fascicle	Sweet orange, ber, plum, cherry
C. Spadix	Banana, arecanut, coconut, date palm
D. Hypanthodium	Fig, pomegranate

9. Classification of fruits based on type of breeding system (which promotes autogamy/allogamy):

1. Self-pollination (Autogamous)	
Cleistogamy: *e.g.* Papaya, Grape	Homogamy: *e.g.* Apricot, citrus, peach, phalsa, dwarf coconut
2. Cross pollination (Allogamous)	
A. Monoecious *e.g.* Muscadine grape	B. Dioecious *e.g.* Papaya, kiwi, pistachio nut
C. Andromonoecious *e.g.* Mango	D. Gynodioecious *e.g.* Fig
E. Dichogamy	
1. Protandry *e.g.* Walnut, *Annona muricata*	2. Protogyny: *e.g.* Sapota, *Annona spp.* banana, fig, pomegranate, plum
Heterodichogamy *e.g.* Peacanut, Pistachio	Duodichogamy *e.g.* Chestnut
F. Heterostyly	
i. Pine type *e.g.* Sapota, Litchi, Pomegranate	ii. Thrum type *e.g.* Almond, carambola
Protogynous diurnally synchronous dichogamy (PDSD) *e.g.* Avocado	
G. Self-Incompatibility	
a. Sporophytic SI	Mango, aonla, cocoa
b. Gametophytic SI	Ber, pineapple, apple, pear, apricot, almond, cherry, loquat

10. Classification of fruits based on mode of pollination:

- **Entomophilous:** Citrus, Annona spp., apple, pear, peach, plum ber, cherry, fig
- **Anemophilous:** Papaya, sapota, jack fruit, pomegranate, Datepalm, aonla, chestnut
- **Ornithophilous** (Humming birds): Banana, pineapple

11. Classification of fruits based on fruit bud:

Fruit bud	Fruit crops
Simple bud	Mango, date palm, coconut, apricot, plum, palm, cherry
Mixed bud	Guava, grapes, ber, pomegranate, apple, pear, cashew

12. Classification of fruits based on hardiness of skin:

Hardiness	Examples
Hard fruits	Wood apple, bael
Soft fruits	Papaya, sapota

13. Classification of fruits based on fruit morphology (Number of ovaries involved in fruit formation):

Type of fruit	Examples
A. Simple fruits	
I. Berry	Banana, papaya, grape, sapota
a. Modified berry	
i. Balausta	Pomegranate
ii. Amphisarica	Wood Apple, Bael
b. Pome	Apple, Pear, Quince, Loquat
II. Drupe (Stone)	Mango, peach, plum, ber
III. Hesperidium	Citrus
IV. Nut fruit	Litchi, Rambutan, Cashewnut
V. Capsule	Aonla
B. Aggregate fruits (Develops from numerous ovaries of the same flower)	
1. Etaerio of berries	Custard apple
2. Etaerio of drupelets	Blackberry, longan berry
3. Etaerio of achenes	Strawberry
C. Multiple/composite fruits	
1. Syconus	Fig
2. Sorosis	Jackfruit, pineapple, breadfruit, mulberry

14. Classification of fruits based on type of placentation:

Type of placentation	Crops
Axil	Banana, citrus
Marginal	Litchi
Parietal	Papaya
Basal	Ber

15. Classification of fruits based on growth pattern:

Growth pattern	Examples
1. Single sigmoid growth curve	Mango, apple, date palm, apple, pear, sweet orange, lemon, strawberry, papaya
2. Double sigmoid growth curve	Stone fruits (peach, plum, nectarine, cherry, apricot), grapes, sweet cherries, fig, olive, raspberry, almond, pineapple, annona
3. Triploid sigmoid growth curve	Kiwi fruit

16. Classification of fruits based on tolerance to shade:

Level	Examples
1. High shade tolerant	Carambola, bilimbi (Cucumber tree)
2. Moderately shade tolerant	Banana, mangosteen
3. Highly shade sensitive	Citrus, mango, guava, coconut

17. Classification of fruits based on acid tolerant fruit crops:

Level	Examples
1. Slightly tolerant to acid soil	Mango, citrus, banana, guava, papaya, apple, peach, kiwi
2. Moderately tolerant to acid soil	Orange, pineapple, jack, avocado, litchi, loquat
3. Highly tolerant to acid soil	Wood apple, bael, strawberry
4. Tolerant to alkaline soil	Guava, date palm, aonla, custard apple, coconut

18. Classification of fruits based on relative salt tolerance fruit crops:

Levels	Examples
1. High tolerance	Datepalm, ber, aonla, guava, bael, coconut
2. Medium tolerance	Pomegranate, cashewnut, jamun
3. Highly sensitive	Mango, citrus, apple, avocado, pear, strawberry

19. Classification of fruits based on their respiratory behaviour:

Climacteric fruits	Non-climacteric fruits
Mango, banana, sapota, guava, papaya, apple, pear, peach, plum, nectarine, annona, fig, apricot, avocado, blueberry, feijoa guava, passion fruit, cherimoya, kiwi, cran berry, rasp berry durian, jack fruit, ber	Citrus spp, grapes, pineapple, pomegranate, rambutan, litchi, ber, jamun, cashew, cherry, strawberry, aonla, phalsa, loquat, olive

20. Classification of fruits based on rate of respiration rate:

Level of respiration	Rate of respiration (mg of CO_2/Kg/hr)	Fruit crops
Very low	<5	Nut, dried fruits
Low	5-10	Citrus, grapes, apple
Medium	10-20	Mango, banana, pear, peach, fig
High	20-40	Strawberry, avocado

21. Classification of fruits based on rate of ethylene rate:

Level of ethylene	Rate of ethylene (γl of C_2H_4/Kg/hr)	Fruit crops
Very low	<0.1	Grapes, citrus
Low	0.1-1.0	Pineapple, watermelon
Medium	1-10	Mango, banana, guava, fig, tomato
High	10-100	Apple, papaya, avocado, plum
Very High	100	Passion fruit, sapota, apple

22. Classification of fruit crops based on storage life:

Very perishable (0-4 weeks)	Perishable (4-8 weeks)	Semi-perishable (6-12 weeks)	Non-perishable (>12 weeks)
Apricot, banana, berry fruits, cherry, fig, loquat, mango, strawberry	Avocado, grape, mandarin, nectarine, passion fruit, peach, pineapple, plum	Coconut, oranges	Apple, grape fruit, lemon, pear

II. Miscellaneous:

1. Derivation of common fruits from various plant tissues

Tissue that can develop into fruit flesh

i. Peduncle: Fig, pineapple
ii. Pedicle: Cashew apple
iii. Accessory tissue: Apple, pineapple
iv. Receptacle: Strawberry
v. Mesocarp: Peach
vi. Pericarp: Grapes
vii. Endoderma interalocular tissue: Orange
viii. Outer layer of testa: Pomegranate
ix. Aril: Mangosteen

2. Edible portion of fruit crops:

Edible part(s)	Fruit crops
Pericarp	Custard apple, avocado, ber, datepalm
Pericarp and placenta	Grape
Mesocarp	Mango, papaya, sapota, passion fruit, mulberry
Mesocarp and endocarp	Banana, aonla, apricot
Mesocarp and epicarp	Peach, plum, persimmon, phalsa, cherry, jamun, karonda
Fleshy peduncle	Cashew apple
Fleshy aril	Litchi
Fleshy receptacle	Fig
Fleshy thalamus	Apple, pear, quince, strawberry, loquat
Thalamus and pericarp	Guava
Succulent placentae	Bael, wood apple
Bracts and Perianth	Jackfruit, pineapple
Juicy placental hairs	Citrus
Juicy seed coat	Pomegranate
Cotyledon	Peacanut, pistachio nut, cashewnut, almond
Endosperm	Coconut

3. Nutritive value of fruits:

Nutrition	Fruits 100g) (Rank wise)
Vitamin-A (β-carotene)	Mango (4800 IU)> Papaya (2020 IU)
Vitamin- B1	Cashewnut (630 mg) > Walnut (450 mg)
Vitamin-B2	Bael (1191 mg) > Papaya (250 mg) > Litchi (122.5 mg)
Vitamin-C	Barbados cherry (1000-4000 mg) > Aonla (600 mg) > Guava (299 mg)
Carbohydrates	Raisins (77.3%) > Dry Apricot (72.8%) > Dry Karonda (67.1%) > Dates (67.8%)
Protein	Cashewnut (21.2%) > Almond (20.88%)
Fat	Walnut (64.54) > Almond (58.9%)
Fiber	Fig > Guava (6.9%) > Almond (0.23%)
Calcium	Litchi (0.21%) > Dry Karonda (0.16%)
Phosphorus	Almond (0.49) > Cashewnut (0.45%) > Walnut (0.38%)
Iron	Dry Karonda (39.1%) > Date (10.6%)
Calorific value	Walnut (687 mg) > Almond (655 mg) > Cashew (596 mg) > Dates (283 mg)

4. Major colour compounds present in fruit crops:

Colour	Pigments	Examples
Orange	β-carotene	Mango, pineapple
Red-purple	Anthocyanins	Grapes, pomegranate, blackberries, raspberries, blueberries
Orange	Caricaxanthin	Papaya
Red	Lycopene	Papaya, guava var. Arka Kiran
Orange-yellow	Flavonoids	Peach, papaya, orange, tangerine
Yellow-green	Lutein and zeaxanthin	Avocado
Green	Chlorophyll	Guava
Yellow	Xanthophyll	Guava

5. Aroma compounds responsible for fruits

Fruits	Compounds
Apple- Ripe	Ethyl 2-methylbutyrate
Apple- Green	Hexanal, 2-hexenal
Banana- Green	2-Hexenal
Banana- Ripe	Eugenol
Banana- Overripe	Isopentanol
Grapefruit	Nootakatone
Lemon	Citral
Orange	Valencene
Raspberry	1-(p-Hydroxyphenyl)-3-butanone

6. Volatile compounds (Aroma):

Fruits	Volatiles
Banana	Isopentyl acetate
Orange	Citral
Almond	Benzaldehyde
Apple	2-methyl butyrate

Aroma of fruits is due by Esters

7. Aroma is due to esters

Fruits	Esters
Apple	Pentyl valerate
Grape	Methyl salicylate
Banana	Pentyl acetate
Orange	Octyl acetate
Strawberry	Ethyl butyrate
Raspberry	Butyl acetate

8. Bitterness is due to flavonoids and terpenoids:

Fruits	Flavonoids	Terpenoids
Orange and Lemon	Hesperidin (Tasteless)	Neral and Geranial
Grapefruit	Naringenin (Bitter taste)	Nootkatone

9. Classification of fruits based on their ploidy levels:

A. Euploidy	
1. Allo-polyploidy	
Allotetraploid/Amphidiploid	Mango
Allo-hexaploid	European plum
Allo-octaploid	Vellaikolamban, Cultivated strawberry
2. Auto-polyploidy	
Auto-triploid	Cultivated banana, Tahiti lime
Auto-tetraploid	Aonla, jack fruit, litchi, phalsa, bael, ber cv. Umran
Auto-hexaploid	Persimmon, Kiwi
Auto-octoploid	Ber cv. Gola, Illaichi
B. Aneuploidy	
Aneuploid-82	Pusa Srijan (Guava dwarf rootstock)

10. Completed and released Genome sequences in fruit crops:

Fruit crops	Genome size	Mapping population	Fully completed
Grapes	500 Mbp	Pinot Noir	2007
Papaya	742.3 Mbp	Sun Up	2007
Apple	372 Mbp	-	2010
Strawberry	250 Mbp	*Fragaria vesca*	2011
Banana	523 Mbp	*Musa acuminata*	2012
Pear	512Mbp	*Pyrus bretschneideri*	2012
Peach	220-230Mbp	-	2010

+ Mbp: Mega base pairs

11. Promising introduced fruit varieties from exotic source in India

Fruit crops	Cultivars	Introduced from
Grapes	Thompson seedless, Perlette, Beauty seedless, Delight Himrod	USA
	Kismish Chorni, Kismish Beli	USSR
Banana	Lady finger	Australia
	Grand Nine	France
Papaya	Solo, Sunrise	USA
Sweet orange	Blood red	USA
Mandarin	Kinnow	USA

C. Tropical Zone Fruit Crops

1. Mango
2. Banana
3. Citrus fruits
4. Grapes
5. Papaya
6. Guava
7. Sapota

1. Mango

1. **King of Tropical Fruits/ National fruit of India/Pride fruit of India/ Hindustan fruit of India/Symbol of love**: *Mangifera indica*: Anacardiaceae: 2n=4X=40: Origin: South East Asia (Indo-Burma)

☆ Pride of garden or choicest fruit of Hindustan

☆ Tropical and subtropical, evergreen fruit crop

☆ Ideal temperature for mango cultivation: 24-27°C

☆ In India, mango is available from March to mid-August

☆ Mango fruits contains highest Vitamin-A (4800 IU) followed by papaya (2020 IU)

☆ Mango seed kernels contain 9.5% protein

☆ India is a leading country in mango area and production in the world

☆ India shares 4% of world mango cultivation

☆ Leading mango producing countries in world: India > China

☆ Mango occupy 34.9% and 20.7% of total fruit area and production respectively with a productivity of 7.3 Mt/ha.

☆ Leading Mango producing states: UP > AP > Karnataka

☆ Mughal period is considered as a gold time of mango cultivation

☆ Emperor Akbar planted one lakh mango trees is designated as Lakh-Bagh in Darbh... Bihar

☆ Mango is a allopolyploid (Amphidiploid) (2n=4X=40)

☆ Vellaicollumban is allo-octaploid (2n=8X=80)

☆ Total edible *Mangifera* species: 60 species reported by Kostermans & Bompared, 1993

☆ The Mangos: Their Botany, Nomenclature, Horticulture and Utilization, a book written by botanists A. J. G. H. Kostermans and J. M. Bompard

Important wild species:

Specific features	Species
Mango species easily peeled like banana	*Mangifera pajang*: Largest fruit among mango relative species
Free stone mango species	*M. similis*
Completely free from fiber	*M. magnifica*
Off season bearing habit	*M.rufocostat, M. swintonoides*
Fruits twice a year yielding species	*M. indica* var. *mekongensis*
Rootstock for waterlogged condition	*M. decandra, M. inocarpoides, M. gedebe*
Resistant to anthracnose	*M.laurina*
Resistant to leaf hoppers	*M.altissima*
Highest TSS (21.7 Brix) species	*M. odorata*
Purple or black colour fruits bearing species	*M. casturi*

☆ Dwarf tree growth, regular bearing, precocity, resistance to malformation and spongy tissue is controlled by single recessive gene

☆ Production of more than one seedlings from the single seed is known as polyembryony

☆ Polyembryony, bunch bearing habit and biennial bearing habit is controlled by single dominant gene

☆ South Indian varieties are polyembryonic, true to type of seedlings

☆ North Indian varieties are monoembryonic, vegetative propagation is necessary for maintenance

☆ Pit size for mango: 1m×1m×1m or $1m^3$

☆ Training is done in 2-3 years old plants

☆ Conventional system: Square system, Spacing: 10 × 10 m, 100 plants/ha

☆ Intercropping can be done up to 5-6 years in mango orchard

Propagation methods:

☆ Mango stones take about 15-25 days for germination

☆ Efficient, economic and rapid method of propagation technique: Epicotyl/stone grafting

☆ Inarching grafting is the most popular method in South India (Commercial propagation)

☆ Veneer grafting popular method in Northern India

☆ Epicotyl grafting commercially practised in Konkan region of Maharashtra

☆ Bottom heat root technique – is used for enhancement of rooting in mango was developed by Reddy and Majumder (1975), IARI, New Delhi

Rootstocks:

☆ Polyembryonic rootstocks: Mylepalium, Goa, Kurrukan, Olour, Chandrakaran, Bellary, Bappakkai

☆ Bappakkai is the best polyembryonic rootstocks for Neelum cultivar

☆ Exotic polyembryonic cultivars: Cambodiana, Carabao, Cecile, Higgins, Pagho, Peach, Apricot, Turpentine, Pico, Sabre, Simmonds, Strawberry

☆ Potential dwarfing clonal rootstock: Totapuri Red Small and Olour

☆ Heading back in mango done at November-December

☆ Pruning time in south india: August-September

☆ Flowerbuds borne in old season growth

☆ Flowering period: 2-3 weeks

☆ No. flower per panicle: 1000-6000

☆ Inflorescence type: Terminal panicle

☆ Types of flowers: Male and hermaphrodite

☆ Type of pollination: Cross pollination

☆ Pollinator: Honey bees

☆ Caging techniques developed by Sharma *et al.*, 1972, IARI, New Delhi (Sharma & Singh)

☆ Flower bud differentiation in India: October to December

☆ Fruit bud differentiation in TN: December-January and North India: February-March

☆ Highest bisexual flower percentage: Langra (69.8%)

☆ Fruit set in shy bearing cultivars: 0.1%

☆ The use P333 or Paclobutrazol or Cultar @ 1.25 to 10 g.a.i/tree. Commercialized in India to manipulate flowering by post- harvest application to the soil significantly promotes flowering and fruiting.

☆ Paclobutrazol is a gibberellins bio-synthesis inhibitor. it controls the emergence of vegetative flush.

☆ Smudging is making the Smokey fire below the tree canopy and allows smoke to through the foliage for several days.

☆ Smudging is practiced in Philippines for inducing early flowering

☆ Improvement of earlier flowering and fruiting: KNO_3 1% at the time of flowering commercially utilized in Mexico

☆ The normal sex ratio is 3:1 of perfect and male flowers.

☆ Critical factor for optimum fruit set: determined by proportion of perfect flowers

☆ Prevention of pre-harvest fruit drop in mango: 2,4-D @ 20 ppm, NAA @ 50 ppm

☆ Fruit type: Fleshy drupe

☆ Optimum storage temperature: 13°C

☆ Mango leather is called "*Am Paper*"

Varieties and its hybrids:

Hybrids	Parents	Special features
Ambika	Amrapali × Janardhan Pasand	Late ripening variety
Arunika	Amrapali × Vanraj	
Pusa Peetember	Amarapali × Lal Sundari	Yellow colour variety, suitable for uniform packaging (due to oblong fruit shape)
Pusa Arunima	Amarapali × Sensation	Regular bearer
Pusa Lalima	Dashehari × Sensation	Red colour variety (bright red peel colour)
Pusa Pratibha	Amarapali × Sensation	Regular bearer (red peel colour)
Pusa Shreshth	Amarapali × Sensation	Regular bearer
Mallika	Neelum × Dashehari	Regular bearer- Mid season
Amrapali	Dashehari × Neelum	Regular bearer, Desert variety
Ratna	Alphonso × Neelum	Regular bearer
Sindhu	Ratna ×Alphonso	Seedless
Arka Udaya	Amarapali × Arka Anmol	-
Arka Aruna	Banganapalli × Alphonso	Regular bearer- Suitable for HDP
Arka Puneet	Alphonso × Banganapalli	Regular bearer- Suitable for canning
Arka Neelkiran	Alphonso × Neelum	Regular bearer- Suitable for export
Arka Anmol	Alphonso × Janardhan Pasand	Regular bearer- Suitable for export
Manjira	Rumani × Neelum	-
Au-Rumani	Rumani × Mulgoa	-
PKM-1	Chinnaswarnarekha × Neelum	-
PKM-2	Neelum × Mulgoa	-
Swarna Jehangir	Chinnaswarnarekha ×Jehangir	-
Neeludin	Neelum×Himayuddin	Regular bearer
Neelgoa	Neelum×Yerra Mulgoa	Regular bearer
Neeleshan	Neelum×Baneshan	Suitable for canning industry
Konkan Ruchi	Neelam x Alphonso	Suitable for pickle purpose
Sai Sugandha	Totapuri×Kesar	Suitable for pulp extraction
Prabha Sankar	Bombay×Kalapady	Regular bearer and late season variety
Sunder Langra	Langra×Sunder Prasad	Free from malformation disorder
Varieties		
Pusa Surya	Selection from Eldon	Apricot yellow peel colour, long shelf life
Neelum	Kasaladdu	Regular bearer, late season mango variety
Totapuri	Kallamai or Kilimooku	Suitable for processing industry (pulp)
Rumani	-	Apple shaped variety
Alphonso	Khader or Badami or Gundu	Suitable for export and susceptible to spongy tissue Most popular variety in india
Dashehari	-	Mid-season, Susceptible to mango malformation Most popular variety of north india
Mulgoa	-	Late season and shy bearing
Langra	Turpentine flavour	Commercial variety in North India, Biennial bearer, Midseason
Paiyur-1	-	Suited for HDP
Niranjan	-	Off-season fruit bearing variety

	-	Regular bearer, Early maturing
Pairi	-	Mid season
Mankurad	Rosy flavour	Regular and heavy bearer
Gulab Khas	Sweetest variety	Late maturing variety
Chausa	Commercial var. in AP	Early maturing variety in south india Commercial variety of Andhra Pradesh
Banganapalli	-	Suitable for processing, commercial variety in Gujarat
Kesar	-	Susceptible to mango malformation Earliest variety of north india
Bombay Green		

Specific features:

- Good mango varieties contain 20% of TSS
- Pusa Surya (syn. Eldon) introduced from Brazil in the year 1981 at the Indian Agricultural Research Institute, New Delhi.
- Kent, Tommy Atkins, Alphonso and Kesar varieties are more demand in the international market
- Alphonso, Dashehari, Kesar and Banganapalli that are currently in demand in the international markets are produced and exported from India
- North Indian mango varieties are alternate bearers e.g. Langra and Dashehari
- Dwarfing cultivars: Ambalavi, Kalapady
- North Indian mangoes Langra and Dashehari are alternate bearers
- Off season mango (Fruit maturity: January to February) : Kanyakumari district of Tamil Nadu due to microclimate; Cultivars: Neelum, Rumani, Bangalora
- Ideal mango varieties should have a high ration of edible to non-edible matters (3.31 to 4.0)
- Regular bearer varieties: Totapuri or Bangalora, Neelum, Ratna, Sindhu
- Most popular varieties in North India: Dashahari, Chausa
- Canning variety: Alphonso
- Off season variety: Niranjan
- Mutant variety: Rosica
- Promising dwarfing genotype: Creeping
- Most suitable variety for canning purpose: Alphonso and Dashehari

Physiological disorders:

Disorders	Causes/Reasons	Remedy
Spongy tissue	High temperature, convective heat, post harvest exposure to sunlight	GA_3 @ 50 ppm
	Spongy tissue loses in Alphonso: 30%	Susceptible: Alphonso Resistant: Ratna and Arka Puneet
Biennial bearing	Climatic factors, C:N ratio, hormonal balance and genetic factors	Soil application of Paclobutrazol @10 g a.i/tree Antigibberellin synthesis: Paclobutrazol
Black tip	Orchard near (600 m) to Smoke of brick-kilns It releases the gases such as CO, CO_2, SO_2 and C_2H_2	Minimized the spray of 0.6 % borax and 0.8 % caustic soda
Cluster of fruitlets/ clustering/jhumka	Low temperature	-
Soft nose	Interactive effect of nitrogen and calcium in the soil	-
Leaf scorching	K deficiency	

Mango Malformation:

- Mango malformation is 1st reported in India from Darbhanga, Bihar by Maries in 1891
- Vegetative malformation (nursery seedlings) more common than floral malformation (bearing stage)
- Susceptible varieties: Bombay green, Chausa
- Resistant varieties: Elachi, Bhadauran
- Prevention of malformation: Deblossoming done with NAA@ 200 ppm

Pest and diseases:

- Nut weevil: *Cryptorrynchus mangifera*
- Mango mealy bug: *Drosicha mangiferae*
- Fruit fly: *Daccus dorsalis*: Major problem in export of mango fruits
- Mango hoppers: (*Amritodus atkinsoni, Idioscopus niveosparsus, I. clypealis*) Most serious pest

- Sooty mould: *Meliola mangiferae*: Honey dew secretions on leaves and flowers
- Anthracnose (*Colletotrichum gloeosporioides*): Most serious storage disease of mango
- Powdery mildew (*Oidium mangiferae*): Most serious disease during flowering stage

2. Banana

2. **Antique fruit crop/Tree of Wisdom/Tree of Paradise/Adams fig/Plant of virtue/Apple of paradise:** *Musa spp.* Musaceae: 2n=2X=22, 33, 44: Origin: Indo-Malayan (South East Asia)

★ Kalpatharu means a "plant of virtue"

★ Plantain means "cooking banana"

  - Origin of *Musa acuminata*: Malaysia
  - Origin of *Musa balbisiana*: Burma

★ Humid tropical herb

★ Monocotyledonous, monocarpic, herbaceous perennial herb

★ Banana leaf is considered as a Biological plate

★ Calorific value of banana fruit: 67-137/100g

★ Banana fruit rich source of Potassium (450 mg)

★ Chilling injury occurs less than 12°C

★ Optimum temperature for banana cultivation: 20-30°C

★ Better quality banana: Mid subtropical condition (Better aroma and crisp pulp)

★ Low temperature 10°C leads to Choke of impeded inflorescence and bunch development

★ Banana is the most consumed fruit crop in india

★ Banana and Plantain is the 4th important food crop in the world in terms of gross value

★ India is the largest producer of banana in the world, contributing 25.57 % to global production from 15.5 % area

★ In India, banana occupy 11.5% of area and 33.4% of total fruit area and production respectively

★ Leading banana producing states: TN > MH > Gujarat

★ Leading banana producing countries in world: India (27.8%) > China > Philippines

★ Wild banana types all are diploids

★ Edible cultivars of banana are derived from interspecific hybridization: *M.acuminata* (AA) × *M.balbisiana* (BB)

Wild relatives:

Features	Species
Species whose flower used as vegetable	*Musa acuminata ssp. malaccensis*
Fibre yielding species	*Musa basjoo* (Used in Japan textiles), *Musa textilis*
Contribution of parthenocarpy origin in banana	*M.acuminata ssp banksii*
Ornamental species	*Musa ornata, Musa flaviflora, Musa velutina*
Tolerant to panama wilt and nematode	*Musa laterita*
Tolerant to panama wilt, nematode and sigatoka leaf spot	*Musa acuminata* ssp. *burmanica*

☆ Plantain types belongs to AAB or ABB genome group

☆ Sweet dessert type belongs to AAA genome group

☆ Fruit type: Berry

☆ Inflorescence type: Spadix (Female and Hermaphrodite flower)

☆ About 40 leaves are formed till flowering

☆ Flowering in banana is proved by dual factor hypothesis- GA induces growth and elongation of stem, Anthesin act as flowering hormone

☆ Parthenocarpy arises from mutation in A genome species

☆ Edible bananas are developed by vegetative parthenocarpy

☆ Parthenocarpy and dwarfness is controlled by single dominant gene (P)

☆ Parthenocarpy in banana: 3 complementary genes

☆ Banana scoring techniques developed by Simmonds and Shepherd (1955)

☆ Botanically, rhizome is a modified form of stem

☆ Propagation: sword suckers, Ideal banana suckers weight 500-750 g

☆ Emerging new suckers is known as "peepers"

☆ Most widely used tissue culture in banana: shoot tip culture

☆ Popular tissue culture variety in India- Grand Nine

☆ Tissue culture banana plants advisable ratooning up to 2-3 times

Planting system

- Burrow planting is mostly practiced in Gujarat and Maharashtra

- Pit planting: used in garden land system
- Trench planting: Cauvery delta of Tamil Nadu

☆ Water requirement for banana: 1,800-2,200 mm per annum

☆ Water can be saved under drip irrigation: 23-32%

☆ Water requirement for banana through drip system- 10-25 litres/plant

☆ Banana exhausting crop it requires large quantity of fertilizers

☆ Banana is a heavy feeder of potassium

Spacing:

Varieties	Spacing
Tallest varieties	3 m × 3 m
Taller varieties Suitable for leaf purpose	2.54 m × 2.54 m
Semi-tall varieties	2.51 m × 2.51 m
Dwarf varieties	1.8 m × 1.8 m

☆ Multi-storey system is commonly followed in coastal Karnataka and Kerala

☆ Banana is grown as a rainfed crop in west coast and hills South India

Special practices:

+ Propping: Pseudostem requires support at the time of bunch emergence
+ Bunch cover: covering bunches with dried leaves or perforated polythene sheets enhances the fruit quality
+ Bunch covering is essential practice in Dwarf Cavendish and Silk group for attractive fruits
+ Denavelling: Removal of malc bud after completion of the female phase
+ Smoke treatment is the commonest method to induce ripening in Tamil Nadu and Maharashtra

Desuckering:

★ Removal of surplus and unwanted suckers from banana plant

★ Two ways of desuckering: Pouring of Kerosene oil and damaging with crowbar, 2,4-D

- Desuckering is done at 3 times in a year
- Climacteric fruit
- Harvesting stage: Days from flower emergence, disappearance of angles

- Storage temperature: 13°C @ 85-95%
- Bunch covering is essential practice in Dwarf Cavendish and Silk group for attractive fruits
- Smoke treatment is the commonest method to induce ripening in Tamil Nadu and Maharashtra
- Acetylene and smoke treatment not good for health
- Ethylene ripening champer 10-100 ppm (0.001% to 0.01%) depending upon the crop, variety and maturity in the chambers at 18 to 24 degrees Celsius with 90% to 95% RH
- Food Safety and Standards Authority of India (FSSAI) provide standard for ethylene safe for human consumption
- Storage temperature: 13°C @ 85-95% RH

Important varieties grown in India:

Common name	Synonym	Genome	Specific features
Dwarf Cavendish	Basrai	AAA	▪ Resistant to Panama wilt ▪ Leading commercial cultivar, 58% of the total banana production
Robusta	Bombay Green	AAA	Semi-tall sport clone of Dwarf Cavendish
Grand Naine	France	AAA	♣ Tall mutant clone of Dwarf Cavendish ♣ Internationally accepted variety ♣ Popular all over india
Gandevi selection	Hanuman paradise		♣ Clone of Dwarf Cavendish
Monthan	Bontha	ABB	Drought resistant, culinary variety
Rasthali	Martaman	AAB	♣ Choicest table variety ♣ Problem: Hard lumps and fruit cracking (peel splitting)
Poovan	Champa	AAB	★ Resistant to Panama wilt ★ Severely affected by Banana streak virus ★ Perennial banana system in plains
Hill banana	Virupakshi, Sirumalai	AAB	♣ Elite banana variety in Tamil Nadu ♣ Perennial banana system in hilly areas (Tamil Nadu and Karnataka) ♣ Double prize banana variety

Nendran	Plantain	AAB	♣ Good keeping quality (15 days) ♣ Most prized cooking variety in kerala ♣ Exporting banana variety products ♣ Suitable for banana chips
Red Banana	Sevazhai	AAA	Long duration of cropping system (16 months), grown only backyard gardens ((Tamil Nadu and Kerala))
Kunnan	-	AB	Popular dessert variety
Ney Poovan	Rasa Kadli	AB	Popular in South India, Double prize banana variety
Karupuravalli	ABB	-	Tolerant to drought, salt, wind and suitable for juice, wine Hardiest variety
BRS-1	Agniswar × Pisang Lilin		AAB- Resistant to Sigatoka leaf spot
BRS-2	Vannan × Pisang Lilin		AAB- Tolerant to leaf spot and Panama disease, rhizome weevil and nematodes
CO-1	(Laden×*M. balbisiana*) ×Kadali		AAB, Pome hybrid
H1	-	-	Highly resistance to leaf spot, fusarium wilt, nematode
FHIA-1	Syn. Gold Finger- AAAB		Resistant to sigatoka and wilt
Udhayam	Selection from single plant "Pisang Awak (ABB)"		Ratoon crop, Field tolerance to Sigatoka, Suitable for long distance and processing
Lady finger	Australia	AB	Resistant to bunchy top virus
Pisang Lilin	-	-	Panama wilt and nematode
Tongat	-	-	Panama wilt and nematode
Anaikomban	-	-	Panama wilt and nematode

Specific features:

- Cavendish bananas occupies 63% of cultivars grown in Indian banana industry
- Poovan cultivar grown commercially in different regions for its wider adaptability and tolerance to drought and diseases

- Rasthali is grown for premium price in the market
- Ney Poovan is becoming commercially importance in South India
- Nendran grown for mainly table and processing industry
- FATOM-1: Early flowering mutant from Grand Naine (G9)
- Plantains (AAB) group: bananas bearing fruit that is starchy at ripening stage
- Almost 60% of all the cultivated bananas in the world belong to the AAA (Autotriploids) group.
- AAA (Autotriploids) group: all the bananas that enter international trade (Gros Michel, Cavendish, and their variant forms such as Robusta, Grand Nain, Williams)
- Most AAA bananas are used as dessert bananas
- The 'Pome' subgroup (AAB) is popular in south and northeast India as dual-purpose cultivars and, in Brazil, as dessert bananas. Several clone groups of the AAB group, such as Silk, Mysore and Pisang Raja are very popular dessert bananas in south and south east Asia
- ABB cultivars are generally hardier and more disease resistant than the other triploid genomic groups.
- They are used primarily for cooking. Better-known clonal subgroups of the ABB cultivars e.g. Bluggoe and Monthan
- FATOM-1: Early flowering mutant of Grand Naine (G9)
- Dwarf Cavendish and Robusta are widely adopted commercial bananas
- Cooking banana varieties: Monthan, Ney Vannan, Nendran
- Varieties suitable for multi-storey system: Poovan and Ney Poovan (Semi-tall banana)
- Resistant to biotic and abiotic stress: Poovan
- Excellent quality banana variety: Rasthali

Ploidy	Genome	Varieties	Score
2X	AA	Matti, Anai Komban, Sanna Chenkadali, Surya Kadali, Namarai, Pisang Lilin, Tongat	16-23
2X	AB	Ney Poovan, Thaen Kunnan, Kunnan, Adakka Kunnan, Nattu Poovan	46
3X	AAA	Robusta, Red Banana, Dwarf Cavendish, Gros Michael, Amritsagar, Chakkarakeli	15-11
3X	AAB	Poovan, Rasthali (Silk), Nendran, Virupakshi, Pachanadan, Sugandhi, Rajapuri	2-6
3X	ABB	Karpuravalli, Peyan, Monthan, Kari Bontha, Kari Montha, Monthan, Kallu Monthan	68
4X	AAAA	Bodles Altafort (Synthetic hybrid, not existing in nature)	
4X	ABBB	Klue Teparod, Sawai (Natural hybrid)	

Physiological disorders:

- ☆ Neer Vazhai: Immature unfilled fingers, lanky bunch and delayed shooting: Transm... through suckers
  - NAA improves the finger filling
  - Nendran is susceptible variety for Neer Vazhai- Causes: Unknown
- ☆ Kotta Vazhai: Enlarged ovules with immature fruits: Poovan susceptible variety ca... unknown
  - Remedy: Spraying of 2,4-D @ 120 ppm
- ☆ K deficiency: Yellow orange chlorosis, Leaf bending, rapid leaf desiccation
- ☆ Marginal scorching is the typical disorder in banana due to potassium deficiency
- ☆ Yellow pulp is physiological disorder: premature and abnormal development of immat... banana fruits. This is associated with excess of 'K' in relation to 'N'.
- ☆ Goose flesh: dry winter season
- ☆ White leaf: unbalanced N
- ☆ Blue disease: Mg deficiency

Pest and diseases:

- Rhizome or Corm weevil: *Cosomopolitus sordidus*: Major pest
- Pseudo stem weevil: *Odiphorous longicollis*
- Banana burrowing nematode (*Radopholus similis*): Most destructive nematode
- Leaf spot (*Cercospora musae*) (Sexual stage) from Java
- Yellow sigatoka leaf spot (*Mycosphaerela musicola*): Most serious disease in subtropica... regions
- Panama disease (*Fusarium oxysporium* f. *sp. cubense*): Severe incidence in acid soil and we... soil- Soil borne
- Moko disease or Bacterial wilt (*Pseudomonas solanacerum*)
- Bunchy top of banana is a virus disease, transmitted by aphids (*Pentalonia nigronervosa*)
- Bunchy top of banana is 1st reported in Fiji (1981)
- Sigatoka disease is 1st reported in Fiji (1913)
- Banana Bract Mosaic Virus (BBMV) is transmitted by Aphids
- Banana streak virus (BSV) is transmitted by Mealy bug (*Planococcus citri*)

3. Citrus Fruits

3. **Citrus:** *Citrus spp.*: Rutaceae: 2n=2X=18

- ☆ The word citrus is derived from *Greek* word
- ☆ Citrus is a mesophyte tree
- ☆ Citrus means fruit of the godly tree
- ☆ Study of cultivation of citrus: Citriculture
- ☆ Among citrus fruits 8 are edible species
- ☆ 3rd most important fruit crop after Mango, Banana
- ☆ Origin of the true citrus fruits is South East Asia, including South China, north-eastern India and Burma
- ☆ Lime and Lemon Origin: Indian or South East China
- ☆ Fortunella and Poncirus are originated from China
- ☆ Citron is originated from North West India
- ☆ India is 4th largest producer of citrus fruits in the world
- ☆ Citrus occupy 14.9% of area and 12.5% of total fruit area and production respectively
- ☆ Leading citrus producing states: AP > MH > MP
- ☆ Leading lime/lemon producer in India: Andhra Pradesh > Gujarat > Telangana
- ☆ Leading sweet orange (Mosambi) producer in India: Telangana > Andhra Pradesh > MH
- ☆ Leading orange (Mandarin) producer in India: Punjab > MP > MH
- ☆ Largest producer of citrus: USA
- ☆ India is at 4th position in world citrus production
- ☆ Leading orange producing countries in world: Brazil > USA > China
- ☆ The world citrus is dominated by sweet orange with a 64% contribution followed by mandarins with 20%,

  Limes and lemons 10% and rest of the 6% shared by grapefruit and other citrus fruits
- ☆ India is the largest producer of lime in the world
- ☆ Italy is the largest producer of lemon in the world
- ☆ Japan is the largest producer of mandarin in the world
- ☆ In India, both mandarins and sweet oranges are grown under tropical climatic c... except Kinnow and Khasi mandarin

☆ Kinnow mandarin, however, commercially successful in north Indian states like Punjab, Haryana and Rajasthan (under subtropical climate with winter season)

☆ The famous Nagpur orange (mandarin) is grown in humid tropical Vidarbha region of Maharashtra where summer temperature reaches as high as 45-46°C

☆ Modern taxonomy system of citrus classification: Swingle and Tanaka system

☆ Synthetic chimera is originated from citron bud inserted on a sour orange seedlings

☆ Synthetic chimeras of citrus is known as Bizzarria (Italy)

☆ Bud and seed mutations leads to formation of sports

☆ Sugar less citrus fruits: Grape fruit and sour orange

☆ High citric acid content citrus fruit: Sour orange (1.5-3%)

☆ High malic acid content citrus fruit: Sweet lime

☆ Smell of citrus trees due to : Hesperidin (Flavonoids)

☆ Development of excellent colour formation in citrus fruit: <13°C

☆ Citrus fruit preferable for candy preparation: Kumquat

☆ Grapefruit is used for preparation of dry and fortified wines

☆ Deciduous citrus species: Trifoliate orange

☆ Kumquat, Trifoliate orange and other citrus → hybridize freely to produce natural hybrids

☆ Monoembryonic citrus species: Pummelo, Tahiti lime, Citron

☆ Monoembryonic citrus cultivars: Lemon *var.* Meyer, Mandarin *var.* Temple and Clementine

☆ Special horticultural practices followed in citrus: Girdling and Ringing

☆ All citrus fruits are tree ripened (non-climacteric)

☆ Self incompatibility is observed in Lemon, Clementine mandarin and Sweet Lime

☆ Ornamental citrus species: Hazara (*Citrus madurensis*)

☆ Self and cross incompatibility exist in citrus

☆ All the edible fruits of citrus comes under the subgenus: Eucitrus

☆ Citrus flowers are produced on current season growth in cymes both axillary and terminally

☆ TSS of the most of the citrus groups: 8-12%

☆ Among the citrus fruits, Mandarins occupied largest area followed by sweet orange, lime and lemons

☆ Most of the citrus species take 6-8 months from flowering to fruit ripe stage

☆ Large petiole wings present in: Grapefruit and Pummelo

☆ Small petiole wings present in: Sweet orange and Acid lime

☆ Type of flowers: Perfect and imperfect

☆ Most of the species of citrus flower colour is white except lemon and citron are purplish on the outside

☆ Special type of berry: Hesperidium

☆ Outermost layer: Exocarp (Flavedo)

☆ Edible portion containing many carpel segments: Endocarp

☆ White spongy portion: Mesocarp (Albedo)

☆ Growth curve of citrus: Single sigmoid curve

☆ Recently, a new propagation technique Microbudding for citrus has been developed at NRCC, Nagpur

☆ Short-term indexing used for detection of exocortis, greening and psorosis

☆ Long-term indexing for xyloporosis

☆ Apomixis is a type of asexual reproduction

☆ Citrus apomixis type: Facultative apomixis

☆ Nucellar embryony: development of embryos from the maternal tissue called the nucellus that surrounds the embryo sac

☆ Nucellar embryony impedes progress in scion breeding.

☆ Polyembryony (multiple embryos in one seed) is associated with nucellar embryony

☆ Bitter glucoside Naringin provides prevention of malaria

☆ Monotypic genus: Poncirus- Highly resistant cold

☆ Ermocitrus is highly drought resistant

☆ Micro grafting: transferring small shoot apices on to rootstocks. It is done through *in vitro* or *in vivo*

used for recovery of citrus clones free from virus diseases

☆ Shoot tip grafting (STG): done for free from virus/virus like organisms

☆ *Citrus limetta* is a species derived from Lime × Lemon

☆ Cross protection technique (Tristeza) is done in Acid lime

☆ National Research Centre for Citrus was upgraded into Central Citrus Research Institution in 2014

☆ Most promising rootstock for acid lime: Gajanimma (*C. pennivesiculata*)

Important lime species:

Common name	Scientific name	Features
Acid lime / Mexican Lime / Sour Lime / Kagzi lime	*Citrus auarantifoila*	Tenderest among citrus species
Sweet lime (Origin: India)	*Citrus limettoides*	Varieties: Mithachikna, Mitho
Rangpur lime (Origin: India)	*Citrus limonia*	Rootstock and ornamental species
Tahiti lime/Persian lime	*Citrus latifoila*	Seedless, Triploid Resistant to cold

Important acid lime varieties:

- ★ Pramalini: Tolerant to canker
- ★ Vikram: Offseason and bunch bearing habit
- ★ Chakradhar: Seedless variety
- ★ PKM-1 or Jai Devi: Seedling progeny of Kadayam local
- ★ Sai Sarbati: Tolerant to tristeza and canker
- ★ Balaji

- Most promising rootstock for acid lime: Gajanimma (*C. pennivesiculata*)
- Cross protection technique (Tristeza) is done in Acid lime
- Sweet lime: important citrus fruit in north India
- Rangpur lime: mostly used for rootstock purpose
- Citrus limetta is a species derived from Lime × Lemon
- Acid lemon commercially grown in india
- Sweet lemon commercially grown in south America and Egypt
- Lemon more tolerant to high altitude regions and frost and hardy in nature
- Suitable rootstock for lemon: Trifoliate orange and Jatti Khatti
- Lemons more prone to fruit cracking

Important lemon species:

Common name	Scientific name/parents	Specific features
Lemon	*C. limon*	Flower colour: Purple
Rough lemon	*C. jambhiri*	Tolerant to *tristeza* and *exocortis*
Hill lemon	*Citrus pseudolemon*	
Bush lemon	Lemon × Citron	Natural hybrid
Citron	*Citrus medica*	Commonly used for pickling

Important Lemon varieties:

- ✦ Lisbon, Villafranca, Lucknow Seedless, Kagzi Kalan, Pant Lemon-1 (Self-incompatible)
- ✦ Eureka, Baramasi, Meyer Lemon, Pat Lemon,

Propagation:

☆ Commercial propagation methods:

- ✦ Acid lime → seeds due to polyembryony
- ✦ Sweet lime → layering and hardwood cuttings
- ✦ Persian lime → ground or air layering
- ✦ Rangpur lime → seeds

Rootstocks:

Commonly used rootstock:

- ☆ Trifoliate orange (*Poncirus trifoliate*): Cold hardy, dwarf rootstock, resistant to *Phytophthora*, *Tristeza* and nematode
- ☆ Tolerant to freezing condition: *C. unshiu*
- ☆ Resistant to salt: *Severinia bouxifolia*
- ☆ Rangpur Lime: Vigorous, hardy rootstock suitable for heavy and deep soil
- ☆ Rough lemon: Tolerant to tristeza, saline and calcareous soil
- ☆ Most common method of planting system: Square system
- ☆ Training system: Single stem
- ☆ Off season fruiting time for acid lime: November to December
- ☆ Cracking or splitting is the major physiological disorder of lime and lemon
- ☆ To increase the fruit set or to reduce the flower drop: 2,4-D @ 20 ppm

Oranges:

- ☆ Sweet orange/tight skinned oranges: *Citrus sinensis:* Origin: Indo-China
- ☆ Highly polyembryonic species, No. of segments: 10-12
- ☆ Commercially grown dry semi arid to subtropical regions in India

Important species:

Common name	Scientific name	Specific features
Sweet orange/tight skinned oranges	*Citrus sinensis*	Origin: Indo-China
Sour orange/Bitter orange (Narthangai)	*C. aurantum*	Used for pickling purpose
Multiple leaf orange	*C. multifolia*	-
Trifoliate orange	*Poncirus trifoliata*	Origin: China
Indian wild orange	*Citrus indica*	-

Important varieties:

- Commercial variety: Mosambi- popular in Maharashtra
- Blood Red Malta (Mid-season variety) commercially grown in North India
- Hamlin- Early variety
- Jaffa-Famous mid-season variety
- Valencia-Late maturing variety
- Sathgudi (Granulation susceptible variety)
- Pineapple is a variety of sweet orange
- Sathgudi is also known as Chini or Chinese orange: Commercially grown in Andhra Pradesh
- Jaffa is suitable for arid region
- Early variety, high TSS sweet orange variety: Mosambi (30%)
- Shamouti- Famous seedless sweet orange variety
- Blood Red Malta: popular in north india
- Seedless sweet orange type: Navel
- Seedless in sweet orange is due to pollen and ovule sterility *eg.* Washington Navel
- Mosambi is an early variety in India

Rootstocks:

- Rangpur lime: Suitable for Mosambi and Sathgudi
- Jhatti Katti and Karna Khatta: Suitable for Blood red variety

☆ Spacing: 6 m × 6 m

☆ Training: Single stem system

☆ Best time for pruning: Late winter or Early spring

Major problems:

☆ Fruit sucking moth in South India whereas Granulation in North India

☆ Phosphorus deficiency in sweet orange is most common problem in North India

Granulation:

- It means drying of juice vessels, insipid taste
- Causes: Due to high temperature, high RH, age and vigour of tree, nutritional status
- Major pre harvest physiological disorder of sweet orange

- 1st reported in California, USA
- To prevention of granulation: 2, 4-D @ 12 ppm and Zn + Cu + K @ 0. 5%

☆ Pre harvest fruit drop is common problem

☆ Mosambi and Malta Blood Red are more prone to pre harvest fruit drop

Mandarin / Tangerine / loose skinned or jacket orange

- Mandarin: *Citrus reticulata*: Origin: China; No. of segments: 10-14

☆ Highly polyembryonic species

☆ Mandarins are mostly grown as rainfed condition in India

☆ It occupies 50% area under *Citrus spp*. cultivated in India

☆ Mandarins are mostly grown as rainfed condition in India

☆ Mandarin grown frost free tropical and subtropical regions in India

☆ Nagpur mandarin grown black clay soil in Nagpur regions

☆ Kinnow mandarin requires warm cool temperature and chilling temperature

☆ Kinnow mandarin grown in alluvial soils

☆ Kinnow mandarin highly adopted to arid and semiarid irrigated zones of Punjab

Important mandarin species :

Common name	Botanical name
Japanese Satsuma mandarin	*C. unshiu*
King mandarin	*C. nobilis*
Willow leaf mandarin	*C. deliciosa*
Wilking	Willow leaf × King
Kinnow mandarin	King × Willow leaf
Cleopatra mandarin	*C. lycopersicaeformis*
Spice mandarin	*C. reshmi*
Tangerine orange	*C. tangerine* (Trifoliate orange × Mandarins)
Tangerine	*C. reticulata* × *C. aurantium* (Dancy Mandarin and Clementine)
Kumquat (Origin: China)	*Fortunella sp.* (Ornamental species)

Important Mandarin varieties:

- ☆ National mandarin variety: Ponkan or Nagpur mandarin
- ☆ Finest variety or mandarin in the world: Nagpur mandarin
- ☆ Fruits available time: January to February
- ☆ Nagpur mandarin fruit colour is orange in colour is due to cryptoxanthin pigment
- ☆ Most commercial variety in South India: Coorg Mandarin
- ☆ Khasi Mandarin: Commercially grown in Assam
- ☆ Khasi or Sikkim or Kamala mandarin: Popular in Assam
- ☆ Commercial mandarin in Japan: Satsuma mandarin (Seedless)
- ☆ **Kinnow mandarin**: King × Willow leaf
  - ♣ Interspecific hybrid developed by Dr. H.B. Frost at Citrus Experiment Station California, USA in 1915
  - ♣ Kinnow was introduced to India (Punjab)-1959
  - ♣ Kinnow popular in Semi-arid irrigated zone of Punjab and Haryana
  - ♣ Polyembryony type
  - ♣ Fruits maturity: mid-January
- ♣ Most of the commercial mandarin cultivars propagated by seeds
- ♣ Commercially propagated by T budding (Kinnow and Nagpur Mandarin)
- ♣ Commercial mandarin in Japan: Satsuma mandarin (Seedless)
- ♣ Sexual seedlings are stunted and poor growth easily rogued out from nucellus originated seedlings
- ♣ Micro budding: Virus free, healthy true to type of plants- Novel and economical methods *eg.* Nagpur mandarin
- ♣ Shoot tip grafting (STG): True to type plants produced free from virus, precocious planting material *eg.* Mandarin and Sweet orange

Spacing:

- Kinnow: HDP using Troyer citrange as a rootstock: 1.8m × 1.8m, 3000 plants/ha. Square system
- Nagpur mandarin: 6m × 6m using Rough lemon rootstock

Crop regulation:

☆ Root pruning is done for regulate the desired flowering season to get more yield

☆ Root pruning is practised in Central and Southern India

☆ Mandarin blooming period: 3 time/year in South and Central India

- ♣ Ambe Bahar: February flowering: Fruit drop (serious problem)
- ♣ Mrig Bahar: June flowering
- ♣ Hasth Bahar: October flowering

☆ Resting or root exposure practised in Deccan region during the month of April-May

Degreening:

☆ Degreening treatment done to improve the aesthetic value (colour) of the fruit

☆ Degreening in mandarin reduced using (before harvest): Ethrel @ 50 ppm spray 1 week before harvesting

☆ Degreening treatment: Ethylene @ 1-5ppm at 20-29°C and 60-90% RH

☆ Storage temperature: 8-10°C @ 85-90% RH

Pummelo/Shaddock: *C. grandis*: Origin: Malaysia

☆ Ancestor of pummelo is grape fruit

☆ Monoembryonic species

☆ Mainly 2 types: White fleshed and red fleshed

☆ Propagation: Air layering

Forbidden fruit /Grapefruit: *C. paradisi:* Polyembryonic species: Origin: Southern China

☆ Grape fruit is a chance hybridization of pummelo and sweet orange: Unique interspecific hybrid

☆ It is cultivated in all the subtropical regions of the world

☆ Grape fruit contains 'Naringin' bitter glucosides-Anti-malarial activity

Grape fruit varieties:

- ♣ White fleshed: Duncan, Marsh, Walters
- ♣ Red fleshed: Star Ruby, Foster, Hudson, , Red blush, Ruby Red, Flame
- ♣ Pink flesh variety: Thompson

☆ Other varieties: Marsh seedless, Ruby, Foster, Triumph

☆ Seedless grape fruit variety: Duncan

☆ Ruby Red - Bud sport of Thompson

☆ White fleshed grapefruit 1st citrus fruit variety to be patented

☆ Propagation: T Budding

Harvesting stage:

- *Mandarin:* Ripe stage: Changes of colour from green to orange colour
- Kinnow is a hybrid between pummelo and grapefruit
- Sweet orange: changes colour from green to yellow or pale colour
- Lime and lemon: Mature Green
- Citrus decline or citrus dieback: Complex disorder-Most susceptible crop: Mandarin
- Citrus blackly is a serious pest in lemon
- Citrus canker resistant species: Citron
- Cross protection used for Tristeza virus free plants
- Greening is 1st reported in India

Artificial hybrids:

Name	Parentage	Special remarks
Citrange	*Poncirus trifoliata* × *Citrus sinensis*	-
Citrangequat	*Citrange* × *Fortunella marginata*	Ornamental species, used for candying
Citrangor	*Citrange* × *C. sinensis*	-
Citcitrange	*Citange* × *P. trifoliata* × *C paradisi*	-
Citrandarin	*P. trifoliata* × *C. paradisi*	-
Citremon	*P. trifoliata* × *C. limon*	-
Citradia	*P. trifoliata* × *C. aurantium*	-
Citrumquat	*P. trifoliata* × *F. japonica or margarita*	-
Procimequat	*(F. japonica* × *C. aurantifolia)*× *F. hindsii*	-
Limequat	*C. aurantifolia* × *F. japonica*	-
Orangequat	*C. reticulate* × *F. japonica*	-
Tangelo	*C. reticulate* × *C paradisi*	cv. Orlando, Sampson, Minneola, Seminole
Tangors	*C. reticulata* × *C sinensis*	cv. Temple, Clementine, Monreal
Lemonlime	*C. limon* × *C. aurantifoila*	-
Lemonnage	*C. limon* × *C. sinensis*	-
Lemandarin	*C. limon* × *C. reticulata*	-

☆ **Intergeneric hybrids:** Citrange, Citrangequat, Citrumelo, Citrandarin, Citremon, Limequat, Orangequat

☆ **Interspecific hybrids:** Lemonage, Lemonime, Lemandarin, Tangor, Tangelo

☆ Trifoliate orange and its hybrid citranges are resistant to citrus nematode (*Tylenchulus semipenetrans*)

Diseases and their vectors in *Citrus spp.*

Diseases	Causal	Vectors	Indicator plant
Tristeza / Quick decline	Closterovirus	Oriental citrus aphids (*Toxoptera citricida*)	Symptoms: Honey combing, pitting of stem, seedling yellows Acid lime
Greening	Bacteria (*Candidatus Liberibacter*)	Citrus psylla (*Diaphorina citri*)	Sweet orange *var.* Valencia, Pineapple
Exocortis	Viroid	Tools (mechanically)	Rangpur Lime
Psorosis / California Scaly butt / Cachexia	Virus	Seeds	Acid lime
Xyloporosis / Scaly butt	Symptom: Bark scabing	Mechanical tools	Sweet lime
Canker	Bacteria (*X. campestris* pv. *citri*)	Leaf miner (*Phyllocnitis citri*)	Acid lime
Gummosis or foot rot	*Phytophthora* spp.	-	-

4. Grapes

4. **Sophisticated fruit crop:** *Vitis vinifera:* Vitaceae: 2n=2X=38: Origin: Caucasia-Asia minor

- Deciduous climber
- Behaves as both deciduous and evergreen
- Indian grapes cultivation is Tropical Viticulture

- Study of wine from grapes/ Cultivation of grapes is known as Viticulture
- Science of wine making: Enology
- Oldest fruit crop grown by man
- Introduction of grapes from Iran and Afghanistan to India by Muslim invaders in 13 A.D
- Christian missionaries in1832 introduced grapes from France to South India
- Grape is the third most important fruit crop in the world
- It is subtropical fruit crop but adopted to tropical conditions
- Summer temperature should not exceed 35°C for grapes cultivation
- Temperature range for flowering: 18-21°C
- Higher night temperature above 25°C requires for fruit ripening and colour development
- Congenial temperature range for bud swelling and growth: 10-15°C
- Congenial climate for coloured grapes: Cool nights and short days
- The 90% of grapes cultivation in India located in: Peninsular India
- India's exportable grapes (>90%) produced in Nasik district of Maharashtra
- Tamil Nadu since 5 crops are taken within two years cycle, with staggering of pruning grape are available almost throughout the year, except in November
- Nearly 90% of the produce in India is consumed by fresh fruit industry
- About 8% of total production of grapes is exported to foreign countries
- Raisin making and are sundried: 26 % of Indian grapes used
- In developed countries, 90% of the production utilized for wine industry
- Leading Grapes producer in India: MH> Karnataka > TN
- Leading grapes producing countries in world: China > USA > Italy
- India is the only country in the world, where table grapes are available during in April-May

Growing System	Adopted States
Two pruning and single cropping system	Maharashtra, Karnataka and Andhra Pradesh
Five pruning and five crops in two years cycle system	Tamil Nadu
Single pruning and Single cropping system	Subtropical conditions of north India in Punjab, Uttar Pradesh, Himachal Pradesh, Jammu and Kashmir, West Bengal and NEH region

- Extensive research on nature and cause of seedlessness in grapes done by E.B.Babcock and F.T. Bioletii
- World well known grapes breeder and geneticist: Dr. Harold P.Olmo
- Grape aroma-Muscat flavour is due to methyl anthranilate
- "Resveratrol" is a natural antioxidant found in red wine and red grape
- Tartaric acid is commercially extracted from grapes
- Predominant sugar in grapes is fructose
- Red wine is anticarcinogenic property
- Red colour in grapes due to anthocyanins (Malvin 40-60%)
- Foxy aroma is caused by Methyl anthranilate
- Flowers are borne laterally in the axil of the leaves on current season growth
- Type of inflorescence: Panicle
- Types of flowers: Male, Female, Hermaphrodite
- Type of fruit: Berry
- Type of parthenocarpy: Sternospermocarphy
- Stimulative parthenocarpy present in Black Corianth
- Edible portion: Pericarp and placenta

Wild relatives:

- ♣ True grapes belongs to sub genera *Euvitis*
- ♣ Wild species of *Vitis* are polygamous dioecious

Common name	Scientific name	Specific features
Progenitor of grapes	*Vitis vinifera ssp. sylvestris*	-
Edible grape species	*Vitis* and *Muscadinia*	-
American grapes/Fox grape	*Vitis larbrusca*	-
European grape /Wine grape/table grape	*Vitis vinifera*	▪ Natural origin from *V. labrusca* & *V. vulpina*, susceptible to Phylloxera ▪ World leading grapes species about 90%
Muscadine grapes	*Vitis rotundifolia*	Dioecious species, resistant to powdery mildew

Summer grape	*Vitis aestivalis*	
Winter grape	*Vitis berlandieri*	Tolerant to high pH
Sand grape	*Vitis rupestris*	Suitable for sweet preparation (Jam, jelly and preserve)
River Bank Grape/Frost Grape	*Vitis riparia*	
East Asian grape	*V. amurenis*	source resistance to fungal disease and frost

- ☆ Commercial cultivars of American grapes mostly originated from *V. labrusca* × *rotundifolia*
- ☆ *V. lanata*: resistance to rain (berry splitting), *V. himalayana*: late ripening trait
- ☆ Formation of pink pigmentation in green grapes: Difference in day and night temperature exceed 20°C during ripening
- ☆ Requires long warm to dry summers and cool winters in temperate regions
- ☆ Tamil Nadu especially in Theni District: 5 crops in two years against only one crop in other parts of India
- ☆ Discovery of Anab-e-Shahi by R.Shankar Pillay in the home gardens in 1930
- ☆ Grape founding father of North India: Sardar Bahadur Lal Singh
- ☆ Grape founding father of South India: R.Shankar Pillay
- ☆ Leading raisin grape variety: Thompson Seedless

Propagation and rootstocks:

- ☆ Commercial propagation: Hardwood stem cuttings (4 node, 4 inches length and 8-10mm in diameter)
- ☆ Commercially used growth regulator for cuttings: IBA @ 2000 in 10 seconds by Quick dip method preferred
- ☆ Time for cuttings: October
- ☆ Best grafting for rootstocks: Wedge grafting
- ☆ Nematode resistant rootstock: *Vitis champini*- Dogridge and Salt Creek, 1613
- ☆ Phylloxera resistant rootstock: Riparia Clorie (*Vitis riparia*) and Rupestris St. George (*Vitis rupestris*)
- ☆ Saline tolerant rootstock: Solanis 1616 (*Vitis Solanis* ×*Vitis riparia* 1616), Dogridge
- ☆ Dogridge: extremely vigorous rootstock
- ☆ Ready for harvest: 100-120 days after pruning

- ☆ Bud break to blooming: 47-70 days
- ☆ Bud forcasting is practised in grapes

Intercultural operations:

- ☆ Training: Bower system best for production of potential yield
- ☆ Highest cost benefit ratio system: Bower system or Arbour or Pandal or Pergola system (1: 02.09)
- ☆ Most widely adopted training method in India: Bower system
- ☆ Overhead trellis or telephone better than bower system, not popular because of high cost
- ☆ Nipping is removal of terminal buds
- ☆ Nipping is done at terminal buds at 12-15 node stage
- ☆ Purpose of nipping: To avoid staggered growth of grape berries
- ☆ Girdling: removal of ring of bark from the trunk: increases the fruit set and fruit size
- ☆ Cluster or berry thinning: GA_3 @ 50 ppm at calyptra stage
- ☆ Purpose of thinning: To improve the colour, reduce the uneven ripening and increase the sugar content
- ☆ Uniform ripening: Ethrel @ 250-500 ppm at berry starts ripening
- ☆ Functionally female (reflexed stamen) varieties: Angoor Kalan, Hur, Banquai Abyad
- ☆ Calyptra stage (cap like structure): Fusion of sepals and petals that is detaches at anthesis time

Pruning

- ❖ Time of pruning in North India: December to January
- ❖ Pruning time for Tamil Nadu: December to January and May to June
- ❖ The 90 % of grapes cultivation in Maharashtra and Karnataka states, follow the two pruning system; first a foundation in April and then forward pruning in October
- ❖ Summer pruning or back pruning- Twice : March to April (Back or foundation pruning)
- ❖ Foundation pruning: remove all canes from arms after harvest to initiate development of new canes
- ❖ Fruit pruning or forward pruning: October, Done in AP, MH, KN
- ❖ Forward pruning: done to allow emergence of a bunch
- ❖ Retaining 4-5 buds for spur pruned cultivars, 6-10 buds for cane pruned cultivars necessary

★ Staggered pruning cultivar: Bangalore Blue

Use of growth regulators in grapes

- Uniform ripening: Ethrel @ 250-500 ppm at berry starts ripening
- Cluster or berry thinning: GA_3 @ 50 ppm at calyptra stage
- Dormancy breaking chemical: Dormex
- Enlargement of panicle growth: GA_3 @ 10-40 ppm
- Berry elongation of grapes: GA_3 @ 30-40 ppm + 2 ppm CPPU
- Bud breaking in North India: Hydrogen Cyanamide (HCN) 1.5%
- Hydrogen Cyanamide: Induces uniform and early bud sprout
- For uniform bud break: Swabbing of buds with hydrogen Cyanamide: 1.5-4% within 2 48 hrs for forward pruning
- Bud breaking in South India: Thiourea @ 4%
- Golden bleached raisin: NaOH @ 0.2 to 03%
- Magnesium deficiency is the world problem in grape cultivation
- International Fruit Genetics (IFG) located at California, USA

Harvesting index

- Grape berries begin to ripening stage is called *veraison*
- Grape guard packaging material contains sodium bisulphite, control the post-harvest fungal diseases
- Under ordinary conditions grapes can easily be stored for 4 to 5 days
- Ideal TSS for processing grapes – 15° Brix
- Ideal TSS for raisin grapes – 22-23° Brix
- Export purpose: TSS more than 18° Brix and berry diameter: ≥ 18mm
- Fe deficiency of grapes is most common in Black soils
- Major nutrient deficiency in grapes growing area in the world: Mg

Important varieties:

Varieties	Parents	Specific features
Seedless cultivars		
Crimson seedless	Introduction from USA	Coloured seedless
Flame Seedless		Short duration variety, suitable for north Indian plains
Beauty Seedless	-	-
Fantasy Seedless		
Thompson Seedless	-	Ruling variety in India
Perlette	-	-
Arka Vati	Black Champa × Thompson Seedless	Suitable for table and raisin purpose
Arka Neelamani	Black Champa × Thompson Seedless	Suitable for table purpose
Sharat Seedless	Selection from Beauty Seedless	Coloured seedless, export variety
Sonaka Seedless	Bud sport of Thompson Seedless	-
Tas-e-Ganesh	Bud sport of Thompson Seedless	-
Seeded cultivars		
Arka Kanchan	Anab-e-Shahi × Queen of Vineyard	Suitable for table and wine purpose, Late maturing
Arka Shyam	Banagalore Blue × Black Champa	Suitable for juice and wine making
Arka Hans	Banagalore Blue × Anab-e-Shahi	Suitable for wine purpose
Anab-e-Shahi		Popular cultivar throughout India
Pachadrakhsha	*Syn.* Bhokri or Green grapes	Best adopted to tropical climate of TN
Muscat	*Syn.* Gulabi, Black Prince, Panner	
Banagalore Blue	*Vitis vinifera* × *Vitis labrusca*	Suitable for juice and wine making
Red globe		Table variety, bold (size > 22 mm)
IARI Varieties		
Pusa Urvashi	Hur ×Beauty Seedless	Tolerant to anthracnose
Pusa Navrang	Madeline Angavine × Ruby Red	Teinturier variety
Pusa Swarnika	-	-
Pusa Aditi, Pusa Trissar		-
IIHR Hybrids		
Arka Shweta	Anab-e-Shahi × Thompson Seedless	Suitable for table and raisin purpose

Arka Majestic	Angur Kalan × Black Champa	Suitable for head system of training
Arka Chitra	Angur Kalan × Anab-e-Shahi	
Arka Soma	Anab-e-Shahi × Queen of Vineyards	Suitable for wine making
Arka Trishna	Bangalore Blue × Convent Large Black	Suitable for wine making
Arka Krishana	Black Champa × Thompson Seedless	Suitable for beverage industry

Specific features of varieties :

- ☆ Self-thinning variety: New Perlette
- ☆ Cane pruned varieties: Pusa Seedless, Kishmish Charni, Gulabi
- ☆ Leading raisin grape variety: Thompson Seedless
- ☆ Spur pruned varieties: Perlette, Beauty Seedless, Bangalore Blue, Early Muscat
- ☆ Tetraploids: Thompson Seedless, Pusa Seedless, Perlette, Black Champa
- ☆ Induced table mutants: New Perlette, Niagara, Robin, Cardinal
- ☆ Table grapes: Thompson Seedless, Bangalore Blue and Beauty Seedless , Arka Shweta, Arka Majestic and Arka Chitra

Raisins

- Raisins are typically sun-dried, but may also be water-dipped, or dehydrated.
- They are produced mostly from seedless varieties such as Black Corinth or Sultana (syn. Thompson seedless)
- The world's largest producers of raisins: Turkey
- Raisins are high-energy food, rich in sugars, and providing 3,400 kcal/kg.
- Raisin grapes in india: Thompson Seedless, Black Corianth, Gold, Kishmish Beli- Seedless with high sugar content

- ☆ Juice grapes: Bangalore Blue, Beauty Seedless, Arka Krishna, Early Muscat, Champion
- ☆ Wine grapes: Muscat Canelli, Black Champa, Arka Soma, Arka Thrishna- High sugar content and low acid
- ☆ Canning grapes: white grapes with larger berries suitable Pusa Seedless, Thompson Seedless, Kishmish Charm, Kishmish Beli, Seedless White
- ☆ Popular raisin grape variety: Arka Vati and Thompson Seedless

- ☆ Juice variety in Tamil Nadu: Gulabhi, Bangalore Blue
- ☆ Coloured seedless varieties: Fantasy Seedless, Sharad Seedless and Crimson Seedless
- ☆ Green seedless varieties: Thompson Seedless, Tas-A-Ganesh, Sonaka
- ☆ Teinturier (French language) means wine term applied for variety having a red colour in skin and flesh
- ☆ Teinturier variety in India – Pusa Navrang

Canning grapes:

- ♣ White grapes with larger berries suitable
- ♣ Pusa Seedless, Thompson Seedless, Kishmish Charm, Kishmish Beli, Seedless White

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Pest and disease

- ☆ Anthracnose (*Elsinoe ampelina*): destructive disease in north india
- ☆ Downy mildew: *Plasmopara viticola*: serious problem in peninsular india
- ☆ Powdery mildew: *Uncinula necator*
- ☆ Grape fan leaf virus transmitted through nematode (*Xiphinema index*)

Physiological disorder in grapes:

Physiological disorders	Reason/Suceptible variety	Remedies
Uneven ripening	Bangalore Blue, Beauty Seedless	Ethephon @ 250 ppm at colour break stage
Post harvest berry drop	Anab-e-Shahi, Beauty Seedless	NAA @ 50 ppm
Flower or Bud drop	-	Stem girdling
Pink berry formation	Thompson Seedless, Tas-E-Ganesh	Ascorbic acid @ 0.2% + Sodium [illegible] dithiocarbamate
Chicken and hen	Boron deficiency	Foliar application of boric acid [illegible]

Millerandae or Shot berries	Boron deficiency	Ethephon 25 ppm + Seven 2000 ppm for 1 minute
Coluere	Boron deficiency	
Blossom End Rot (BER)	Calcium deficiency	Foliar application of $CaNo_3$ @ 1%
Interveinal chlorosis	Mg, Zinc, Iron	-
Bunch necrosis	Tas-A Ganesh	

5. Papaya

5. **Wonder fruit of tropics and subtropics/tree melon/backyard fruit/breakfast fruit/papaw:** *Carica papaya*: Caricaceae: 2n=2X=18: Origin: Tropical America

- Tropical fruit tree, mainly grown as a backyard tree
- Introduced in India during 16th century period
- Sensitive to frost, strong winds and highly susceptible to water logging or stagnation
- It provides more income/ha next to the banana
- Highest remunerative crop (Highest net return/unit area) than any other fruits crops
- Among the fruits, papaya (2020 IU) is the 2nd rich in Vitamin-A after mango (4800 IU)
- Papaya rich source of calcium(30 mg/100 g)
- Papain contains proteolytic enzyme or protease helps in digestion of protein rich foods
- Yellow fruit colour pigment of papaya: due to presence of caricaxanthin
- Latex is obtained from green papaya fruit
- Papain is used for digests proteins and is used as a meat tenderizer, as a digestive medicine in the pharmaceutical industry, in beer brewing, tanning industries and in the manufacture of chewing gum.
- Carpine is obtained from papaya, utilized for diuretic and heart stimulent
- Papain is used in extracting oil from the liver of 'Tuna Fish'
- Optimum temperature for
  - Papaya cultivation: 30-35°C
  - Seed germination: 30°C
  - ...tive growth: 21-33°C

- High temperature (>35°C) leads to female sterility
- Stamen carpellody is the development of misshapen or cat-faced fruits due to fusion of the stamens to the ovary tissues in hermaphrodite flowers
- Carpellody formation: below 20°C, low elevation/cool winter
- Male plants bear fruits in summer season is known as carpellody
- Continuous flowering and fruiting observed throughout the year
- India is the largest producer of world in the world
- Leading Papaya producing states: AP > Gujarat > MH
- Highest productivity: Tamil Nadu (198 Mt/ha)
- Leading papaya producing countries in the world: India (43.7%) > Brazil > Indonesia
- Papaya is usually dioecious tree but hermaphrodite and gynodioecious types are also observed and utilized for breeding programme
- Karnataka is the highest production and productivity in India
- Type of fruit: Large hollow fleshy berry
- Type of inflorescence: Axillary panicles
- Type of placentation: Parietal placentation
- Highly cross pollinated crop; Pollinator: Wind
- Papaya seed is enclosed with gelatinous layer: Sarcotesta
- Narrow gene pool (less genetic variation)
- Sibmating is practiced in papaya breeding to avoid inbreeding depression, to maintain the genetic uniformity
- Sibmating means crossing of female and male progenies of same parent
- Solo (450-650 g) small fruit preferred for tropical countries
- Metaxenia effect is found in papaya

☆ **Important species:**

☆ Carica is the only genus of Caricaceae containing domesticated species: *Carica papaya*

☆ Badillo (1993) divided the genus Carica into two sections, *Carica* and *Vasconcella*

Common name	Scientific name
Mountain papaya	*Vasconella candamarcensis* (Previously known as *Carica candamarcensis*)
Frost resistant species	*V. candamarcensis* and *V. pentagona*
Distortion ring spot virus resistant species	*V. cauliflora* (PRSV)
Hardiest species	*V. quercifolia*
Monoecious species	*V. monoica*

Sex forms in papaya:

- ☆ Polygamous plant, Predominant 3 sex forms- Male, Female and Hermaphrodite
- ☆ Classification of sex forms in papaya was proposed by Storey (1958)- 8 sex form
- ☆ Papaya sex is controlled by single gene with 3 alleles: M_1, M_2, m
- ☆ Sex reversing male: M_1RR_m or M_1Rr_m
- ☆ Maleness is controlled by satellite chromosomes
- ☆ Sex reversal in papaya is governed by a single gene (R)
- ☆ Red skin and red pulp colour of papaya is governed by single recessive gene
- ☆ Red skin colour is present only in gynodioecious papaya
- ☆ The sex of the plants can be identified only after flowering
- ☆ Male: Female ratio in dioecious variety: 1:1
- ☆ Female: bisexual (hermaphrodite) ratio in gynodioecious variety: 1:2
- ☆ Thinning: Keeping one male tree for every 20 females, the excess male trees should be removed.
- ☆ Best nutrient analysis: Petiole 4th leaf
- ☆ Commercially propagated by seeds (500 g/ha or 200 g/acre)
- ☆ 1000 seed weight: 14.5 g
- ☆ Seed viability: 45 days
- ☆ 1g seeds contain 20 seeds
- ☆ The seeds are non-recalcitrant and can be dried to moisture levels of 9-12% for long-term storage
- ☆ For seed production purpose, papaya fruits harvested at colour break stage
- ☆ Germination takes place in15 to 20 days
- ☆ Induction of femaleness in papaya enhance by spraying of GA_3 50 ppm
  - Spacing: 1.8 m × 1.8 m
  - High density planting (HDP) : 1.2 m × 1.2 m (6,400 plants/ha): Suitable variety: Pusa Nanha
  - Spacing for papain production: 1.6 m × 1.6 m
- ☆ Planting time: June to October and January to March
- ☆ K is required for TSS content of latex and the enzyme activity
- ☆ Average fruit yield: 60-75 t/ha
- ☆ The economical life of papaya only 2-3 years

- ☆ Harvesting stage: Light green with tinge of yellow at apical end
- ☆ Osmotic dehydration is done for the concentration of fruit pieces
- ☆ Chilling injury symptoms include skin scald, hard lumps
- ☆ Room cooling and forced air cooling are most commonly used to pre-cooling method

Papain:

- Latex obtained from ½ to ¾th mature fruits
- Milky latex obtained from 70-90 days old mature fruits
- Latex preserved using KMS 0.05%
- Drying temperature: 45-50°C
- Annual yield of papain: 250-375 kg/ha/year
- CO-5 yield about1500-1600 kg of dried papain/ha

Papain

Important varieties:

Varieties	Breeding methods	Specific features
TNAU Varieties		
CO-1	Selection- Ranchi type	-
CO-2	Selection- Local type	Suitable for papain extraction
CO-3	CO-2 × Sunrise Solo	Suitable for home gardening
CO-4	CO-1 × Washington	Purple pigmented variety
CO-5	Inbred selection from Washington	Suitable for papain extraction 1500-1600 kg dried papain/ha
CO-6	Inbred selection from Giant	Dual purpose (both table and latex-Papain)
CO-7	Coorg Honey Dew × CP-85 Gynodioecious	Gynodioecious variety
CO-8	-	Pink flesh variety
IARI Varieties		
Pusa Delicious	-	Gynodioecious type
Pusa Majesty	-	Gynodioecious type, tolerant to vir... and nematode
Pusa Giant	Suitable for tooty-fruity and candy	Dioecious, Suitable for canning, ...nt to strong winds

Pusa Dwarf	-	Dioecious
Pusa Nanha	Mutant variety (Extremely dwarf)	Suitable for HDP, kitchen garden pot & roof cultivation
IIHR varieties		
Coorg Honey Dew	Selection from Honey Dew	Gynodioecious
Solo	-	Gynodioecious
Arka Surya	Sunrise Solo × Pink Flesh Sweet	Gynodioecious, free from papaya odour
Arka Prabhath	Arka Surya × Tainung-1	Gynodioecious hybrid, free from papaya odour
Pink Flesh Sweet	-	Good dessert variety
Pant Papaya-1	-	Dioecious
Ranchi	-	All 3 sex forms- Male, female and hermaphrodite
Washington	-	

Special features:

- Popular private company Gynodioecious hybrids: Red lady, Zinda
- Transgenic variety: Sunup and Rainbow, Hawaii
- Gynodioecious cultivars: Solo, Sunrise Solo, Taiwan, Thailand, Waimanalo
- Suitable for kitchen gardens, pot and roof-top cultivation: Pusa Nanha (Extremely dwarf variety)
- Surya: Sunrise Solo× Pink Flesh Sweet
- High carotene content: Sunrise Solo
- Highest papain variety: CO-5
- Hortus Gold cultivar developed by Dr J.D. Hofmeyer
- Transgenic papaya developed for resistance to papaya ringspot virus disease using coat protein
- Transgenic papaya commercially grown in Hawaii (1992)
- The world first transgenic papaya variety: SunUp
- First transgenic commercial variety: Rainbow

Pest and diseases:

Diseases	Scientific name/transmission	Features
Papaya mealybug	*Paracoccus marginatus*	Outbreak occurred in Tamil Nadu during 2009 Recommended bio-control agent: *Acerophagus papaya* (Parasitoid)
Foot rot/collar rot/stem rot	*Pythium aphanidermatum*	Soil borne- More severe in rainy season
Anthracnose (fruit surface rot or stem-end rot)	*Colletotrichum gloeosporioides*	major storage disease
Papaya leaf curl virus	Transmitted by whitefly (*Bemisia tabaci*)	Major problem in North India
Papaya Ringspot virus (PRSV or PRV) (papaya mosaic virus or distortion ringspot virus)	Transmitted by aphids(*Aphis gossypii* and *Myzus persicae*)	Major problem in India

6. Guava

6. **Apple of the tropics/Poor man's apple**: *Psidium guajava*: Myrtaceae: 2n=2X=22; Origin: Tropical America
   - ☆ Introduced by Portuguese-17th century in India
   - ☆ Ideal fruit crop for nutritional security in India
   - ☆ 4th most important fruit crop in India
   - ☆ Leading Guava producer in India: MP> UP> Bihar
   - ☆ Fruits are rich source of vitamin-C: 260-300mg/100g
   - ☆ Vitamin-C content is highest in fruit peel at mature stage
   - ☆ Guava contains highest fibre content: 6.9%
   - ☆ Most suitable fruit crop for jelly making due to presence of high pectin content
   - ☆ Highly sensitive to water logging and frost
   - ☆ Trees are resistant to drought
   - ☆ Type of placentation: Axial

☆ Type of fruit: Multiple seeded berry

☆ Type of inflorescence: Cyme

☆ Highly cross pollinated crop (Honeybees)

☆ Calyx break stage: suitable for hybridization work

☆ Red fruit flesh colour controlled by single dominant gene

☆ Best quality guava is obtained during the period of winter season (Night temperature <10°C)

Important species:

Common name	Scientific name	Specific features
Brazilian Guava/Guinea Guava	*Psidium guineese*	Small fruits with poor quality
Strawberry/Cattleya Guava	*Psidium cattleianum*	Purplish red colour small fruits
Costa-Rica-Guava/China guava	*Psidium friedrichsthalianum*	Small fruits globose in shape, Dwarf rootstock and nematode, resistant to guava wilt
Guisaro guava	*Psidium molle*	-
Mountain guava	*Psidium montanum*	-
-	*Psidium pumilum*	Source of high sugar content/dwarf effect
-	*Psidium cujavillis*	Source for high Vitamin-C, source for largest fruit size

- Highly seeded or less seeded types are diploids whereas seedless are autoploidy-triploids (2n=3x=33)
- Guava seedless varieties produce 2 types of fruits: Partially seeded and Completely seedless
- Easiest and cheapest method of propagation: Stooling
- Stooling: shoots were ringed, applied with IBA (2500ppm) in Lanolin and earthed up as a mound to induce rooting
- Seed germination improved through HCl treatment
- Commercially propagated by Inarch grafting
- Recently CISH, Lucknow recommends wedge grafting suitable for rapid multiplication
- To induce multiple cropping in a year (concurrent pruning technique is done during the month of May, September and December
- Flowers are borne on current season growth terminally or laterally
- Best time of planting: June to July

- Preferable training system: Open centre
- Guava flowers (white in colour) and fruits borne in current seasons growth
- Guava fruiting season 3 crops/year in Maharashtra and Tamil Nadu

High density planting in Guava

Spacing	Planting system	Spacing	Total number of plants	Variety
Traditionally	Square system	5 m × 5 m or 6 m × 6 m	278 to 400 plants / ha	L-49
HDP	hedge-row system	6 m × 3 m	555 plants / ha	Allahabad Safeda
Meadow orchard system		1 m × 2 m	5000 plants / ha	Allahabad Safeda

- Using dwarfing rootstock Aneuploid No.82 rootstock in Allahabad Safeda: 10 x10 feet accommodating 1111plants/ha is recommended

Crop regulation:

- Guava yields thrice in a year viz., rainy, winter and summer which constitute to about 70, 27 and 30 % yield
- Ambe bahar: Spring flowering and fruit ripening at rainy season
- Mrig bahar: Rainy season flowering and fruit ripening at winter season
- Hasth bahar: flowering at October and fruit ripens at March
- Highly preferred bahar in India: Mrig Bahar
- Preferred bahar season: South india: Ambe bahar, North india: Mrig
- Mrig bahar: Most preferred (winter crop) because fruits highly superior in quality
- Guava crop regulation includes restricted irrigation, root pruning, deblossoming and [illegible] practices
- Growth regulators very effective for thinning flowers and manipulating the cropping season e.g NAA, NAO, 2, 4-D
- To reduce the rainy season crop- Deblossoming done through applying NAA @ 6 [illegible] + Urea @ 1.5%
- Guava thinning agent: NAA @ 80-100 ppm at 10% of anthesis (NAD, 2,4-D)
- GA_3 induces parthenocarpy fruits
- Spraying of @ GA3 15-30 ppm effective for increasing fruit set

Harvesting:

- ☆ Time required from flowering to fruit maturity: 130 to 150 days
- ☆ Climacteric fruit
- ☆ Fruit development follows double sigmoid growth curve

Maturity index:

- ♣ Harvesting stage: Green firm stage
- ♣ For long distance: Half mature fruits

Pest and disease:

- ☆ Guava fruit fly (*Daucus dorsalis*): More dangerous pest during Rainy season fruit crop
- ☆ Guava scales (*Pulvinaria psidii*): Serious pest in Northern India
- ☆ Tea mosquito bug (*Helopeltis antonii*)
- ☆ Guava wilt is caused by *Fusarium solanii, Fusarium oxysporium, Macrophomina ph* and *Rhizoctonia bataticola*-most prevalent disease in North India- More in alkaline soil
- ☆ Anthracnose (*Gloeosporium psidii* and *Colletotrichum gloeosporioides*): Most se disease
- ☆ Stylar end rot: *Phomopsis psidii:* This disease introduced via. Beaumont guava culti India

Physiological disorder:

- ☆ Bronzing:
  - ♣ Major complex nutritional disorder due to P, K, Zn
  - ♣ Bronzing is severe during rainy season
  - ♣ Free from bronzing cultivar: Allahabad Safeda

Varieties:

Varieties	Breeding methods	Specific features
Pant Prabhat		
Harijha	-	Popular variety in Bihar
Allahabad Safeda	-	Most popular cultivar in UP
Allahabad Surkha	-	Pink flesh and large fruited variety
Chittidar	-	Highest TSS guava variety (small red s presence in skin)
Ganesh Khind Fruit Research Station (GKFRS), Pune by GS Cheema and Deshmukh		
Lucknow-46	-	Pear or pyriform fruit shape
Lucknow-49	Sardar Guava: selection from Allahabad Safeda	Highest Vitamin C variety; national variety
Nagpur seedless	-	-
Safed Jam	Allahabad Safeda × Kohir	-
Kohir Safeda	Kohir × Allahabad Safeda	-
IIHR, Bangalore		
Arka Amulya	Allahabad Safeda × Triploid-Seedless	-
Arka Mridula	Seedling selection from Allahabad Safeda	-
Arka Kiran	Kamsari × Purple local	Pink flesh soft seeded, high lycopene variety
Arka Rashmi	Kamsari × Purple local	Pink flesh dual purpose, soft seeded, suitable for HDP
Central Institute of Subtropical Horticulture (CISH), Lucknow, Uttar Pradesh		
CISH-G-1	Seedling selection from Allahabad Safeda	Red colour and longer shelf life
Lalit	Seedling selection from Allahabad Safeda	Red colour pulp
Shweta	Selection from haf-sib population of Apple colour	Colour variety (pink flesh)
HAU, Hisar		
Hisar Safeda	Allahabad Safeda × Seedless	-
Hisar Surkha	Apple colour × Banarasi Surkha	Pink flesh hybrid
TRY (G)-1	Selection	Off-season, drought, s tolerant
Apple Colour		Red skinned guava variety
Hafshi	-	Red flesh
IARI, New Delhi		
Pusa Srijan (2n=24) (Aneuploid-82)	Potential dwarfing rootstock for HDP Tetrasomic type of aneuploidy (2n+2)	Tolerance to wilt Recommended for dwar stock

		from IARI
Others		
Giant guava Thailand	Introduced from Bangladesh	
Behat Coconut		
Seedless varieties: Saharanpur Seedless, Nagpur seedless		

7. Sapota

7. **Chikku/Sapodilla**: *Achras sapota*: Sapotaceae 2n=2X=26: Origin: Tropical America

- ★ Slow growing, evergreen, humid tropics, long lived tree
- ★ Drought tolerant tree
- ★ Chickle made from milky latex of bark and immature fruits is the base material in chewing gum and statues
- ★ Rich source of Vitamin-A (410 IU/100g) and Potassium (344mg/100g)
- ★ Sapota fruit contains 12-14% sugar content
- ★ Leading state in production and productivity of India: Maharashtra
- ★ Cultivation taken up for the 1st time in Maharashtra in 1898 in a village Gholwad
- ★ Commercial product: Gutta perdha, milky latex (stem) forms the base of the manufacture of chewing gum
- ★ Leading sapota producing states: MH>Karnataka>Gujarat
- ★ It has long pre-bearing age
- ★ Types of pollination: Allogamous-Aneomophilous (Wind pollinated) crop
- ★ Flowers are protogyny in nature
- ★ Fruits are borne on current season growth in the axils of the leaves

Closest genus belongs to Sapotaceae family:

Common name	Scientific name
Black sapote	*Diospyrous digyra* (Ebenacace)
Green sapote	*Calocarpum viride*
Mammey saptoe	*Pouteria sapota*
Star apple	*Chrysophyllum cainito*

- ★ Double sigmoid growth
- ★ Type of fruit: Berry
- ★ Edible part: Mesocarp
- ★ Number of seeds/ fruit: 0-12 (Most common 3 to 5 seeds)
- ★ Commercial propagation: Inarching/Approach grafting
- ★ Soft wood grafting efficient and best technique (Ideal time: July to August)
- ★ Commercial Rootstocks used in sapota: Adam's apple- *Manilkara kauki*, Star apple, Mee tree- *Bassia latifolia*, Mahua- *Madhuca latifolia*
- ★ Spacing: 8 m × 8 m, 156 trees/ha
- ★ HDP spacing- 5 m × 5 m
- ★ Training system: Central leader system
- ★ Planting system: Square system
- ★ Commercial rootstock in sapota: Pala/Khirnee/Rayan (*Manilkhara hexandra or Mimusops hexandra*)
- ★ Suitable intercrops: papaya, banana
- ★ Fruit setting is a major problem in sapota orchard
- ★ Natural fruit setting about: 10-12%
- ★ Fruit drop is mainly due to self-incompatibility
- ★ For improvement of fruit set: Spraying of NAA @ 100-300 ppm during flowering
- ★ Sapota takes 7-10 ½ months for anthesis to maturity of fruits
- ★ Peak period of harvest: February to June and September to October
- ★ Uneven ripening is a problem in sapota
- ★ For ripening: Ethrel @ 1000 ppm with NaOH at 20-25°C
- ★ Orchard decline is a major problem in 8-10years old trees
- ★ Climacteric fruit
- ★ Maturity stage: Ease with brown scruff gets off on the surface and no green tissue and milky latex
- ★ Production problems in sapota: long pre-bearing phase, the large stature of the trees, [illegible] set, flower and fruit

Pest and diseases

- Wilt or die-back is common problem in sapota: *Fusarium spp.*

- Chiku moth or Leaf webber (*Nephopteryx eugraphella*) is most destructing pest
- Leaf spot (*Pharvophelospora indica*) is most serious disease in India
- Phanerogamic parasite *Loranthus sp.* is most common problem in sapota orchards.

Varieties:

Varieties	Parents	Specific features
Horticultural College and Research Institute, TNAU, Coimbatore		
CO-1	Cricket Ball × Oval	-
CO-2	Clonal selection from Baramasi	-
CO-3	Cricket Ball × Vavilavalasa	Suitable for HDP
Horticultural College and Research Institute, TNAU, Periayakulam		
PKM-1	Clonal selection from Guthi	Dwarf, Bearing throughout the year
PKM-2	Guthi × Kirth Barthi	-
PKM-3	Guthi × Cricket Ball	Suitable for HDP, cluster bearing habit
PKM-4	Clonal selection from OP of PKM-1	Spindle shaped fruits, Suitable for dry flakes production
PKM-5	Clonal selection from Virudhunagar	Off-season bearer
UAS, Dharwad, Karnataka		
DHS-1	Kalipatti × Cricket Ball	-
DHS-2	Kalipatti × Cricket Ball	-
Baramasai, Chhatri, Pala, Guthi, Calcutta special round, Oval,		
Kalipatti	Popular in MH	Excellent quality
Murabba	Popular in MH	-
Cricket Ball	Popular in AP	-
Kirthi Bharti	Popular in AP	Good transport value

D. Humid Zone Tropical Fruit Crops

- ♣ Pineapple
- ♣ Jackfruit
- ♣ Mangosteen
- ♣ Avocado

Humid Zone Fruits

1. Pineapple

1. **Heaven fruit/Friendship fruit**: *Ananas comosus*: Bromeliaceae, 2n=2X=50, 75, and 100, Origin: Brazil

☆ Pineapple is a spanish word

☆ Monocotyledonous, monocarpic , herbaceous perennial herb

☆ Pine apple is a obligate Crassulacean acid metabolism (CAM) plant

☆ Xerophytic (leaves) and CAM brings able to withstand prolonged drought

☆ Pineapple rich source of Vitamin-A: 50 IU/100g and Vitamin-C: 50 mg/100g

☆ Most common processed product of pineapple: Canning

☆ Leading pineapple producing states: WB > Assam > Tripura

☆ Leading pine apple producing countries in the world: Thailand > Costa Rica > Brazil

Pine apple drought resistance due to presence of

- Position and trough shape of the leaves
- The presence of trichomes
- Stomata located in furrows beneath trichomes on the underside of the leaf

☆ Symbol of friendship and hospitality: Pineapple crown or Pineapple

☆ Humid crop and drought resistant crop

☆ Best pH range for pineapple cultivation: 4.5-5, to reduce the incidence of heart and root rot caused by *Phytophthora* spp.

☆ Pineapple leaves are silvery white in colour due to the presence of trichomes

☆ North East India produce world best quality of pineapple due to high TSS and less fibre

☆ Suitable intercrop in banana, coconut and arecanut

☆ Most of the pineapple varieties are diploids 2n=2X=50

Important species:

★ Ancestor of cultivated pineapple: Brazilian pineapple: *Ananas microstachys*

★ *Pseudoananas* is monotypic genus

★ Tetraploid species (*Pseudoananas sagenarious*): 2n=4x=100, don't form any suckers

★ Potentially fibre yielding and long spineless leaves species of pineapple: *Ananas erectifolius*

★ *A. ananssoides*- High sugar and acid, resistant to nematode, wilt, heart rot and root rot

★ *A. bracteoutus*- Resistant to wilt, heart rot and root rot

★ *A. segenarius*-Immune to heart rot, root rot and resistant to wilt

★ *Ananas comosus* is the only self incompatible species in the genus

★ *Ananas comosus* var. *variegates*: Ornamental species- Red coloured fruit and variegated leaves

☆ Somatic mutation is very common in pineapple cultivars

☆ Extraction of strong white leaf fibres used for silk 'pina' cloth and cordage (rope) preparation

☆ Pineapple fruit contains an proteolytic enzyme called 'bromelin' *i.e* active constitutent- Improves the digestion

☆ Optimum temperature for pineapple cultivation: 22-32°C

Flower induction

- Natural or precocious flowering naturally occurs during cool weather with short day condition
- Pineapple generally produce flowers after 12 months (35-40 leaves)
- Natural flowering period: December to March
- Forcing plants into flowering allows synchronization of harvest and makes it possible to control harvest dates

Ethephon (2-chloroethylphosphonic acid) is probably the most widely used chemical in commercial pineapple flower production because of its effectiveness and ease of application.

- Flower enhancement: NAA @ 10 ppm + Urea 2% @ 50 ml or 2% Urea @ 0.04% + NaCO3
- Adjusting the solution pH above 7 with sodium borate improves forcing success.

☆ Type inflorescence: Compact spike (100-200 flowers)- Self sterile

☆ Type of incompatibility: Gametophytic SI

☆ Seedless due to presence of Vegetative parthenocarpy

☆ Type of fruit: Sorosis (syncarpous or multiple fruit)

☆ Mode of pollination: Humming birds only in South America other parts of regions by parthenocarpy

☆ Edible portion of fruit is peduncle

☆ Gametophytic Self-incompatibility: Major hindrance of pine apple breeding

Varieties/Groups:

- Smooth Cayenne group is the more productive in tropical conditions
- Queen group is grown mainly in subtropical areas
- Kew and Giant Kew (Commercially grown in India)
- Queen is an earliest variety ripening in June to July, Produces more slips and suckers
- Kew (Fibreless variety)- Leading commercial variety and highly suitable for canning, Shy suckering habit
- Mauritius- Mid season variety of Queen group-Red skinned type
- Indigenous types: grown in Assam (1. Lakhat-sour type, 2. Jaldhup-sweet type)
- Natural tetraploid variety: James Queen or Z Queen (By mutant of Netal Quene)
- Ideal variety for canning: Smooth Cayenne

Hybrid: Amritha (Kew × Ripley Queen):1st hybrid in India Pineapple Research Centre, Mannuthi, KAU.

☆ Major cultivar in North East India: Giant Kew and Queen

☆ Natural triploid variety: Cabezona or Bull Head

☆ Smooth Cayenne is triploid (2n=3X=75), artificially obtained in Hawaii

☆ Smooth Cayenne: quantitatively short day variety

☆ Shy suckering cultivar: Smooth Cayenne

☆ Slips free variety: Hilo

☆ Most commonly grown variety: Smooth Cayenne- Spineless leaves and resistance to gummo

☆ - ideal for canning

Propagation

- Main propagated materials; crown, slips, suckers
- Crowns (fruit tops) produces fruits at after 18-24 months,
- Slips (shoots borne on vestigial fruits at the base of the fruit), produces fruits at after 15-
- months
- Suckers (shoots borne at any position on the stem) produces fruits at after 12-17 months
- Ideal plant material: Slips (350 g) and Sucker (450 g)
- Best planting material: Slips (300-450 g)

☆ Planting time under rainfed crop (Hills): June-August

☆ Spacing: HDP: 22.5 cm × 60 cm × 90 cm (63400 plants/ha)

☆ Nutrient or fertilizer analysis done in pineapple done at the D leaf stage (45°angle)

☆ D-leaf means recently matured leaf with maximum physiological activity

☆ D-leaves are in the fourth whorl from the base of the plant

☆ Single row system is most preferred for ratoon cropping system

☆ Trench planting is widely practised method in India

☆ Earthing up is important cultural operation followed in pineapple

☆ Ratooning is done in Assam more than 25-30 years

☆ Commonly recommended ratooning system: 4-5 years

☆ **Pineapple flowering**: Ethephon/Ethrel is used for uniform flowering

- ✦ Ethrel alone: 100ppm or Ethrel combination: 25ppm of ethrel+2% urea+0.04% $CaCO_3$/$NaCO_3$
- ✦ Role of urea: Increase the absorption of plant system
- ✦ Function of $CaCO_3$: Increase the ethylene release by regulating the pH of Ethephone
- ✦ Stage for flowering induction: 39-42 leaf stage
- ✦ Increase the fruit size: NAA @ 300 ppm

☆ Fruits takes times to ripen: 4 ½ -5 ½ months

☆ Harvesting stage:

- ✦ Canning and distant market: Fully matured fruits
- ✦ Table purpose: Golden yellow colour

☆ Non-climacteric fruit

☆ Pineapple ready for harvest after about 15-22 months

Pest and diseases:

☆ Mealy bug (*Dysmicoccus*) *brevips*) is serious pest of pineapple (Vector for pineapple wilt)

☆ Pineapple mealy bug wilt is caused by a closterovirus associated feeding by the mealybugs, Suceptible variety Cayenne

☆ Base rot/leaf rot/ fruit rot: *Ceratostomella paradoxa*

☆ Heart rot or Stump rot (*Phytophthora parasitica*): Emits foul smell-Predominant in alkaline soil- Severe in dry and wet regions

Physiological disorders:

☆ Sunscald is a physiological disorder due to exposure of fruits to sunrays

☆ Multiple crown is due to genetical factor, climatic, edaphic factors

☆ Sunscald is due to direct fall of sunrays on exposed area of the fruit

☆ Sunburn is common during hotter periods (>35°C)

2. Jackfruit

2. National fruit of Bangladesh/Poor man's food/Jack:

Artocarpus heterophyllus: Moraceae: 2n=56: Origin: India (Western Ghats)

☆ Prefers humid tropical climate

☆ Basic chromosome number: n=14

☆ Tetraploid fruit crop

☆ Multipurpose tree (food, timber, fuel and other)

☆ Monoecious evergreen tree

☆ World's largest tree borne fruit (30-40 kg weight)

☆ Suitable for homestead farming and high density multispecies cropping systems (HDMCS)

☆ Fruit flesh rich source of β-carotene: 500-530 IU/100g

☆ Lectine: Natural protein found in jack fruits- Used for cancer treatment

☆ An extract of jackfruit is called "*Jacaline*" inhibited the growth of HIV infection in *invitro*

☆ Type of pollination: Cross

☆ Mode of pollination: Wind (Aneomophilous)

☆ Male spike bore on terminal shoot or branch of tree crown or main stem

☆ Only female ones develop into multiple fruit: Sorosis

☆ Female inflorescence called as "food stalks". It borne on tree trunk or older branch

☆ Flowering time: December to March

☆ Erratic flowering habit observed in jack fruit

☆ Tree has long juvenile phase: 7-8 years

Related species:

- Bread fruit (*Artocarpus altilis*)
- Monkey Jack (*Artocarpus lakoocha*)
- Semi-wild in Western ghats and bears edible fruits: *Artocarpus hirsuta* (Aini)

☆ Other related species in family Moraceae: Bread fruit, Fig, Mulberry, Monkey Jack

☆ 2 Groups: Firm flesh and Soft flesh

Cultivars:

- Muttam Varikka
- Gulabi: Rose scented cultivar
- Hazar: Bearing large no. of fruit
- Champa: Flavour like champak

Varieties:

- Singapore or Ceylon Jack: Introduced from Ceylon- Off season variety
- Hybrid Jack
- Burliar-1
- PLR-1-Jack (Palur): Fully ripe fruits have flat stigmatic surface instead of a spiny surface: Off season: Suitable for HDP
- PLR-2
- PPI-1 (Pechiparai-1): (2 Crops/year)
- Swarna, Konkan prolific, Kachahalli

Specific purpose:

- Rudrakshi: Pummelo sized fruits
- Suitable for table purpose: NJT-1,2,3,4
- Suitable for culinary purpose: NJC-1,2,3,4
- Uttar Pradesh types: Rasdar, Khajwa and Sugandh
- Exotic varieties: Golden Nugget, Black Gold, Lemon Gold

☆ Commonly propagation: Seeds (Recalcitrant seeds)

☆ Soaking seeds NAA @ 25 ppm for 24 hrs improve the germination

Pomology

☆ Germination time: 3-8weeks

☆ Planting time: June- September

☆ Flowering time: December- March

☆ Required time from fruit set to maturity: 120-140 days

☆ Maturity indices: Flattening of spines on the rind and thickening of latex

☆ Climacteric fruit

Pest and Diseases:

☆ Jack fruit borer (*Diaphania casesalis*): Major pest

☆ *Rhizopus* rot is major disease of jack: Attack male spikes, premature shedding of tender fruits

☆ Fruit rot or soft rot is caused by *Rhizopus artocarpi*: Serious disease and affected fruits fall off early

3. Mangosteen

3. **Queen of tropical fruits/Fruit of the Gods or energy tablet/ Finest fruit of the world/Mystery fruit:** *Garcinia mangostana*: Clusiaceae (Guttiferae):2n=2X=24: Origin: Indonesia or South East Asia

☆ Prefers humid tropical climate

☆ Broad leaved evergreen tree

☆ Shade tolerant tree

☆ Polyploidy tree arises from natural hybridization between *G. hombrniana* and *G. molaccensis*

☆ Natural staple food for man

☆ Ultra-tropical fruit crop: due to adaptation of high temperature and humidity

☆ Only fruit in which glucose is readily available form for giving energy

☆ Thailand is the leading producer in the world

☆ Red colour of rind is due to presence of cyanidin-3-glucoside

☆ Aroma of fleshy aril is due to hexyl acetate

☆ Fruit is ideal for treatment of cancer, tuberculosis and leukemia

☆ Type of fruit: Berry

☆ Number of carpels: 4-8

☆ Flowers produced at terminal portion of branches are solitary

☆ Type of fruit development: Parthenogenesis (seed forms without pollination and fertilization

☆ **Variety:** Jolo

☆ Commercially propagation: Seeds (zygotic)- Recalcitrant seed and occurs polyembryony

☆ Planting time: May to November

☆ Fruits require about 90-105 days to reach maturity after set

☆ Stage of harvest: Green brown to dark brown or reddish purple

☆ Harvesting time: June to September

☆ Harvesting is done fruit with peduncle

☆ Main season of mangosteen: August to October

☆ South Indian hilly areas it flowers twice a year

☆ Storage period: 20-25 days (under normal condition)

☆ Keeping quality is longer compared to other tropical fruits

☆ Major problem in mangosteen: Slow growth rate of tree and lack of root hairs

Physiological disorders:

☆ **Gamboge:**

- Excessive exudation of yellow latex by branches and fruit pericarp due to high RH

☆ Translucent flesh disorder (TFD) is major limiting factor in mangosteen cultivation – Cause Heavy rainfall during pre-harvest

☆ Splitting of fruits

4. Avocado

4. **Alligator pear / 21st century fruit/Fruit of New World/Butter fruit**: *Persea americana* Lauraceae: 2n=2X=24: Origin: Tropical America (or Central America)

☆ Subtropical and evergreen fruit tree

☆ Resistant to cold temperature

☆ In India, it is grown as a backyard tree (Lower Palani hills in Western Ghats)

☆ Other important species belongs to Lauraceae: Cinnamon and Camphor

☆ Fruits rich source of fat (26.4%) and low sugar content

☆ Fruit is rich source of oil ranges from 5-30%- Used for cosmetics industry

☆ Recommended as high energy food for diabetics

☆ Energy value is twice as much as banana fruit

☆ Optimum temperature for flower induction: <25°C

☆ Suitable for low temperature condition: Mexican race

☆ Tolerant to salinity: West Indian race

☆ Type of fruit: Fleshy berry (one-seeded berry)

☆ Type of inflorescence: Compound panicle of raceme

☆ Flowering behaviour: Protogynous diurnally synchronous dichogamy (PDSD) enhances the cross pollination

☆ PDSD was 1st reported by Bergh (1969)

☆ Mode of pollination: Honey bees

☆ Recalcitrant seeds, Viability of seeds: 2-3 weeks

☆ Commonly propagation: Seed

☆ Frost resistant rootstock: Mexican types

☆ Spacing: 5 m × 5 m

☆ Climacteric fruit

☆ Harvesting time: August to September

☆ Harvesting index determined through: Oil content

☆ Botanical varieties: Bergh and Ellstrand, University of California, Riverside, USA (1986)

Avocado races:

Particulars	Mexican race (*P.americana* var. *drymifolia*)	Guatemalan race (*P. americana* var. *guatemalensis*)	West Indian race (*P. americana* var. *americana*)
Climate	Semi-tropical	Subtropical	Tropical
Cold tolerance	High	Medium	Low
Salt tolerance	Low	Medium	High
Oil content	30% (highest)	8 -15%	3 -10%
Months to mature	6 months	>12 months	5 months
Varieties	Duke, Topa	Lula, Hass, Green	Pollock, Purple

Varieties:

☆ Fuerte: Hybrid of Mexican and Guatemalan races: Most popular or leading cultivar- Fairly resistant to cold

☆ Hass: World famous cultivar, more suitable to subtropical climate and turn purple on ripening

☆ Paradenia Purple Hybrid (PPH): Borne in clusters

☆ Duke seedlings are resistant to root rot and cold hardiness

☆ TKD-1: Early maturing

Pest and diseases:

☆ Greedy scale (*Hemiberlesia rapax*): Major pest

☆ Fruit rot (*Colletotrichum gloeosporioides*)

☆ Root rot (*Phytophthora cinnamomi*): Most serious disease in avocado plantations

Physiological disorders:

☆ Mesocarp discolouration- due to polyphenol oxidase enzyme (PPO)

☆ Tipburn is due to chloride toxicity: Most prevalent in spring season

☆ Grey pulp: More prevalent in warmer areas

☆ Pulp spot

☆ Fizzles

☆ Apoplexy

E. Subtropical Zone Fruit Crops

1. **Litchi**
2. **Rambutan**
3. **Loquat**
4. **Durian**
5. **Persimmon**
6. **Passion Fruit**
7. **Egg Fruit**

1. Litchi

1. **Kind of fruits/Queen of subtropical fruit /Lychee/Fruit of high commerce:** *Litchi chinensis:* Sapindaceae: 2n=2X=30: Origin: South China

☆ Evergreen subtropical fruit, luscious fruit

☆ Litchi fruit called as a special fruit

☆ Fruit arils delicious, juicy and refreshing taste

☆ Major organic acids present in the fruits is malic acid: 80%

☆ Fruit rich in vitamin-C: 40-90 mg/100g

☆ High rainfall and humidity induces the vegetative growth

☆ Dry autumn and winter essential for good flowering.

☆ Slow growing deep rooted tree

☆ Related species: Rambutan and longan

☆ Introduce to India during 17th century period

☆ Largest producer of litchi in the world: China

☆ Highest area, production and productivity in India: Bihar

☆ Largest producer of litchi fruit in India: Bihar (40%)

☆ Red colour skin of fruits is due to anthocyanin

☆ Requires high RH and high litre content in soil

☆ Starts bearing 6th year onwards

☆ Type of inflorescence: Branched panicle

☆ Flowers are petalless

☆ Type of fruit: One seeded nut

☆ Edible portion: Aril

☆ Seedlessness is due to stimulative parthenocarpy

☆ Highly cross pollinated crop

☆ Pollinator: honeybees

☆ Litchi has only 2 species: *Litchi chinensis* and *Litchi philippinesis* (Used as a rootstock)

☆ Commercially propagated by air layering or gootee or marcottage (July to September) from year old shoots

☆ Commercial planting system: Square system

Varieties: Soharpaur, Dehradun, Haak Yip, Talso or Mauritius, Waichee, Rose Scented, Muzaffarpur, Bombai- Commercial cultivar in West Bengal, China

Eary varieties	Mid season varieties	Late varieties
Muzaffarpur, Saharanpur, Shahi, Purbi	Dehradun, Rose Scented, Mclean	Calcuttia, China, Bombai, Elaichi

☆ **Recent varieties:** Sabour Madhu: (Purbi × Bedana) and Sabour Priya: (Purbi × Bedana)

☆ Swarna Roopa (Seedless)- Highly resistant to fruit cracking 1st variety developed in India CHES, Ranchi

☆ Calcutta-Hardy variety

☆ Regular bearer varieties: Shahi, Rose Scented and Dehradun

☆ Alternate bearing or irregular bearing variety e.g: China

☆ Fruit bunch bearing clone: Shahi

☆ Table purpose variety: Purbi, China, Calcuttia, Bomabai, Gulabi, Shahi-Pride of Bihar, suitable for canning

☆ Pre-bearing age: 7 to 8 years

☆ Girdling (cincturing) done to control the timing of flushes to start when temperatures are ideal for flowering

☆ Harvesting time: May to June (Summer month)

☆ Litchi fruit very short period of (45-60 days) fruit maturity

☆ Highly perishable fruit

☆ Litchi pericarp is prone to enzymatic browning

☆ Sulphur dioxide fumigation is common practice for colouring into pale-yellow to pink pericarp

☆ Post-harvest losses in litchi production about: 20-25%

☆ Major problem: Fruit drop and alternate bearing or irregular bearing varieties e.g. China

☆ Fruit drop is a serious problem in litchi cultivation

- Causes: Failure of fertilization, embryo abortion, high temperature, low humidity, nutritional and moisture stress

☆ Fruit drop is controlled by IAA @ 40 ppm and NAA @ 20 ppm

☆ Non climacteric fruit

☆ Time required to mature from fruit set: 50-60 days

☆ Most dependable index of maturity is change colour in fruits

Pest and diseases:

☆ Eriophyid mite (*Aceria litchi*): Major pest of litchi

☆ Severe problem in the varieties of Bombai, China, Kasba

☆ Red rust (*Cephaleuros virescens*) most serious disease

Physiological disorders:

☆ Chicken tongue is the physiological disorder of litchi is due to embryo abortion

☆ Fruit cracking: Major problem in the world

☆ Sun burning

2. Rambutan

2. **Rambutan / Hairy litchi**: *Nephelium lappaceum*: Sapindaceae: 2n = 22: Origin: Malayan Archipelago

☆ Strictly a tropical fruit

☆ Prefers moist warm climate

☆ Humid zone fruit crop

☆ High temperature loving tree

☆ Inflorescence develops from terminal buds of past season growth

☆ Fruits require 4 to 5 months to develop and reach harvestable stage

☆ Problem: Alternate bearing

☆ Main season of harvesting: July to September

☆ Litchi and Rambutan produces flowers that near the periphery of the crown

☆ Panicle contains male, female and bisexual flowers

☆ Rambutan is a cross pollinated crop

☆ Suitable varieties for canning and fresh consumption: varieties: Rongrien and Chompu

☆ Cultivated varieties are monoecious in nature

☆ Harvesting time: August to September

3. Loquat

3. **Japanese medlar/Japanese Plum**: *Eriobotrya japonica:* 2n=32: Origin: Southern China

☆ Evergreen, subtropical fruit crop

☆ Used as a ornamental tree

☆ Spain is the largest producer in the world

☆ Fruit is botanically a pome

☆ Pome means consisting of 5 carpels united and covered by edible portion of fruit

☆ Fruit is rich source of vitamin-A: 500-2300 IU/100g

☆ Seeds and peels contain amygdalin content which is converted to HCN cause toxic symptoms to children

☆ Limiting factor for loquat cultivation: Frost

☆ Commercial propagation: Inarching

☆ Flowers are produced on current season shoots

☆ Types of pollination: Cross

☆ Mode of pollination: Bees

☆ Seedlessness in loquat is due to triploid

☆ To induce seedlessness in loquat: GA_3 @100-200 ppm

☆ Fruits are suceptible to sun burning or purple spot

☆ Flowering time: October to late January

☆ Time requires to take fruit maturity: 70 days after fruit set

☆ Non-climacteric fruit

Varieties:

Early varieties	Mid season varieties	Late season varieties
Golden Yellow, Improved Golden Yellow, Large Round, Thames Pride, Pale Yellow-Self incompatible	Fire Ball, Improved Pale Yellow, Large Agra, Mammoth, Matchless, Safeda	California Advance, Tanaka

☆ Popular varieties: Golden Yellow, Improved Golden Yellow, Pale yellow, Large Round, Thames Pride, Fire Ball, Improved Pale Yellow, Safeda, Mammoth, Matchless, Advance, Tanaka, Ahdar, Akko-13, Asfar

☆ 1st triploid variety: Kibou

☆ Partially fertile varieties: Advance and Tanaka

☆ California Advance is the best pollinizer for Improved Golden Yellow variety

4. Durian

4. **King of fruit in Indonesia/Durian**: *Durio zibethinus*: Bombaceaceae: 2n=2X=56: Origin: Malaysian regions (specifically Borneo)

☆ Prefers humid climate

☆ Root decotion to cure fever and leaves for curing jaundice

☆ Fruit have aphrodisiacal properties

☆ Responsible for fruit flavour: Hydrogen sulphide, ethyl hydrosulphide and dialkyl polysulphide

☆ Aril is rich source of Vitamin-C: 33 mg/100g

☆ Arils used for making durian cake: Lempok and Durian jelly (Tempoyak)

☆ National fruit of Malaysia and Indonesia

☆ Largest producer in the world: Thailand

☆ Recalcitrant seeds

☆ Flowering habit: Rauliflorous (Flowers are borne on trunk and branches)

☆ Type of inflorescence: Cyme

☆ Type of cross pollination: Cross

☆ Edible portion: Aril

☆ Major pollinator: Bats

☆ Self incompatibility and heterostyly is observed in durian

☆ Long living tree: 8-150 years

☆ Five loculed fruit has 2-3 seeds in each locule

☆ Commercial propagation: Seeds

☆ Spinless variety: Davao

☆ Fruit ripen during May to September

☆ Harvesting time: August to September

☆ Climacteric fruit

☆ Hawk moth is a serious problem

5. Persimmon

5. **National fruit of Japan/Persimmon/Ebony tree**: *Diospyros kaki*: Ebenacace: 2n=2X=46 Origin: China

☆ Subtropical fruit

☆ Allohexaploid fruit crop

☆ Deciduous, Monoecious fruit crop

☆ Edible portion: Epicarp and mesocarp

☆ Rich in vitamin A (2710 IU/100g)

☆ Fruits are highly astringent is due to tannin content

☆ Flowers appear in spring season on current season growth

☆ Type of flowers: Male, Female, Bisexual

☆ Type of pollination: Cross pollination

☆ Mode of pollination: Insects

☆ Persimmon fruits exhibit a double sigmoid growth curve

Important species related to persimmon:

- Date Plum: *Diospyros lotus*
- American Plum: *Diospyros virginiana*
- Japanese or Oriental Persimmon: *Diospyros kaki*

☆ Flowering time: February

☆ Fruiting time: August

Training system:

★ Dwarf and semi-dwarf: Modified central system

★ Vigorous types: Palmette or vase system

Varieties:

- **Astringent cultivars:** Hachiya, Nightingale, Flat Seedless, Triumph, Hyakuma
- **Non-astringent cultivars:** Fuyu, Wase Fuyu , Hana Fuyu, 20th century, Jiro, Suruga

☆ Sujika: Formation of white lines on the rind of the fruit

☆ Most preferred fruit: PCNA type cultivars: Fuyu and Jiro

☆ Commercially grown in India and also leading commercial cultivar in California: Hachiya

☆ "Cincturing" is the removal of a strip of bark from around the drunk of a tree

☆ Removal of astringency in persimmon fruits: Ethephon @ 500 ppm

☆ Major problem in persimmon: Alternate bearing

Physiological disorders:

- Calyx cavity dehiscence is a serious problem
- Skin russeting is due to high RH
- Calyx end cracking

6. Passion Fruit

6. **Passion fruit**: *Passiflora edulis*: Passifloraceae: 2n = 2X = 18: Origin: Tropical America or Brazil

☆ Produces hen's egg sized fruits

☆ Perennial woody vine

☆ Long day plant

☆ Brazil is the largest producer in the world

☆ Dried flowers contain an alkaloid 'passiflorin' which is used for relieving pain and inducing sleepness

☆ Flowers are borne singly in the axils of leaves at the terminal region of new growth

☆ Fruits bears only on current season's growth

☆ Flowers are protandrous in nature

☆ Self incompatibility is reported in yellow passion fruit

☆ Type of pollination: Cross (Pollinators: Bees)

☆ Type of fruit: Berry

Important species:

Common name	Botanical name	Special features
Purple passion fruit	*Passiflora edulis*	More productive, higher elevation
Golden/yellow passion fruit	*Passiflora edulis* f. *flavicarpa*	Resistant to *Fusarium* wilt, *Phytophthora* blight and resistance to nematodes and *Alternaria* leaf spot
Blue passion fruit	*Passiflora caerulea*	Resistant to *Fusarium* wilt, *Phytophthora* stem rot, tolerant to viruses
Banana passion fruit	*Passiflora mollissima*	-
Water lemon/Golden or Bell apple	*Passiflora laurifolia*	-

Varieties:

- IIHR: Kaveri (Purple × Golden): F_1 hybrid: Resistant to collar rot, wilt, brown leaf spot and nematodes
- Hybrids between purple and golden passion fruit have resistance to nematodes, passion fruit woodiness virus (PMV) and *Fusarium* wilt
- Noel's Special: Tolerant to *Alternaria passiflorae*

Cultivars: Purple Gold, E-23, Black Beauty, Lacey

- Tropical climate: Yellow passion fruit and its hybrids
- Commercially propagation: Seed
- Ideal training system: Two arm kniffin system
- Harvesting time: 2 main periods *i.e.* August-December and March-May

7. Egg Fruit

7. **Canistel/Egg fruit**: *Pouteria campechiana*: Sapotaceae
   - Evergreen fruit crop
   - Fruit appearance and texture look like egg yolk
   - Lesser known fruit of America
   - Rich source of vitamin-A: 2000 IU/100g
   - Commercial propagation: seeds

F. Temperate Zone Fruits

1. Apple
2. Pear
3. Plums
4. Peaches
5. Cherries
6. Strawberry
7. Kiwi fruit
8. Apricot

IV. NUTS

9. Almond
10. Walnut
11. Peacanut
12. Botanical classification of minor temperate fruit crops

Botanical classification of temperate fruits

Fruit Crops	Scientific name	Somatic chromosome number (2n)	Flower colour	Family	Type of fruit
Apple	*Malus domestica*	34	White to Pink	Rosaceae	Pome
Pear	*Pyrus communis*	34	White	Rosaceae	Pome (presence of grit cells)
Quince	*Cydonia oblonga*	34	White or pink	Rosaceae	Pome
Peach	*Prunus persica*	32	Pink	Rosaceae	Drupe
Plum	*Prunus spp.*	32	White	Rosaceae	Drupe
Almond	*Prunus amygdalus*	32	White	Rosaceae	Drupe
Apricot	*Prunus armeniaca*	32	Yellowish red cheek	Rosaceae	Drupe
Cherry	*Prunus spp.*	32	White or Rose	Rosaceae	Drupe
Walnut	*Juglans regia*	32	-	Juglandaceae	Indehiscent drupe
Peacanut	*Carya illioensis*	32	-	Juglandaceae	Nut
Pistachio	*Pistacia vera*	30	-	Anacardiaceae	Dry drupe

European Chestnut	*Castanea sativa*	24	-	Fagaceae	Nut
Persimmon	*Diospyros spp.*	60	White	Ebenaceae	Berry
Cultivated Olive	*Olea europea* var. *communis*	46	-	Oleaceae	Drupe

1. Apple

1. **King of temperate fruits/Symbol of health/Premier fruit of the world**: *Malus × domestica*: Rosaceae: 2n=2X=34: Origin: South Western Asia

☆ Subfamily: Pomoideae

☆ Deciduous fruit tree

☆ Most widely grown temperate fruit in the world

☆ Dry temperate region is most suitable for apple cultivation in India

☆ Apple bowl of India: Himachal Pradesh (HP)

☆ Apple occupy 4.3% of area and 2.8% of production in total fruits cultivation

☆ Leading apple producing state: Jammu & Kashmir (66%)

☆ Apple grown at altitudes of 1,500-2,700 m. above M.S.L. in the Himalayan ranges which experience 1,000-1,500 hours of chilling

☆ Ideal temperature for growing season is around 21-24°C

☆ Among the fruits apple have long storage life

☆ Stone cells are absent in the flesh

☆ Major sugar: Sorbitol

☆ Type of fruit: Pome

☆ Edible portion: Fleshy thalamus (mesocarp)

☆ **Plant architecture:**

- ✦ Orthotrophic shoot, rhythmic growth and terminal flowering: Apple
- ✦ Orthotrophic, rhythmic growth and lateral flowering: Peach, cherry, apricot

☆ Most of the cultivated apple varieties are diploids (2n=2X=34)

- ✦ Ancestor of cultivated apple: *Malus sylvestris*
- ✦ Sucker free species: *M. siversii*
- ✦ Apomixis species: *M. sieboldii*
- ✦ Indigenous to Himalayas: *M. baccata* var. *himalacia, M.sikkimmensis*

☆ Crab apple: cultivated for ornamental purpose due to their attractive colour of flowers and fruits

☆ Crab apple excellent source of disease resistance and used as a pollinizer

☆ Resistant source to scab disease: *Malus × floribunda* Single dominant gene*(Vf)*

☆ Resistant to powdery mildew: *M. zumi* (Pl2): Single dominant gene

☆ Tolerance to very low winter temperatures introduced from *M. baccata*

☆ Fruit colour is controlled by 3 independent genes (A, B, C)

☆ Cream yellow flesh colour is controlled by single dominant gene

☆ Apple low chilling varieties requires <800hrs below 7°C

☆ Apple seed stratification in moist sand at 4-7°C for 60-90 days

☆ Tongue grafting is the ideal method of grafting scion cultivar on the rootstock

☆ Common method of propagation of clonal rootstocks of apple: Stooling or mound layering

☆ Major problem in clonal apple rootstocks: Root suckering

☆ Most critical period of water requirement in apple: April to August

☆ Clean basin management is the common practice of floor management in apple

☆ Thomas Andrew Knight produced the 1st apple cultivar of known parentage

☆ Largest collection of apple genotypes: Plant Genetics Resource Unit, Cornell University, Ithaca, New York

☆ In India recommended pollinizing trees: 11-30%

☆ Heading-back, i.e. removing the apical part of the tree to stimulate bud break below the pruning cut.

☆ Notching, i.e. removal of a thin band of bark above each lateral bud.

☆ Most common method of planting system: Square system

☆ Super high density planting or meadow orchard: 20000-70000 plants/ha: Popular in European countries

☆ Ringing and scoring is practised in apple for reduce the vegetative growth and increase the flower bud formation

☆ Major problem: Alternate bearing

Fruit drop in apple:

- ✦ Early drop: due to pollination and fruit competition
- ✦ June drop: due to environmental factors
- ✦ Preharvest drop: Most serious economical loss. Control: NAA @10 ppm

☆ Apple fruit thinning agent: Carbaryl or Sevin @ 750-1000 ppm or NAA @10-20 ppm

☆ Apple varieties are self unfruitful due to self incompatibility

Special features	Varieties
Introduced variety from USA	Red Delicious, Starking Delicious
High yielding apple variety	Scarlet Gala, Red Fuzi
1st scab resistant variety	Prima
Flavour rich variety	Honey Crisp
Pollinizer variety	Golden Delicious
New scab resistant variety	Honey Crisp, Empire, Jonagold
Spur type varieties	Red Chief, Red Spur Delicious, Golden Spur Delicious
Colour sport varieties	Royal Red, Vance Delicious
Low chilling varieties	Vared, Michael, Tropical Beauty
Early maturing varieties	Yandik-Ovskoe, Papisovka Canniaga
Triploid varieties	Baldwin, Mutsu, Bramlays Boskop, Kaiser, Jonaglod, Wilhelm
Natural mutant	Red Elstar (Parent cv. Elstar)
Scab resistant varieties	Prima, Priscilla, Liberty, Fordous, Shireen, Sir Prize, Freedom
Bitterpit suceptible varieties	Yellow Newton, Golden Delicious, Gravenstein
Pollinizer variety	Golden Delicious, Red Gold
Low chilling varieties for table purpose	Michael, Schlomit, Anna, Tamma, Vared and Neomi
Low chilling varieties for processing purpose	Tropical Beauty, Perlins Beauty
Suitable for processing varieties	Tropical Beauty and Perlin's Beauty
Resistant to wooly aphid	Northern Spy

Varieties:

Varieties	Parentage	Special features
Lal Ambri	Red Delicious × Ambri	-
Sunehri	Ambri × Golden Delicious	-
Akbar	Ambri × Coxs Orange Pippin	Tolerant to scab and powdery mildew (PM)
Ambred	Red Delicious × Ambri-57	Low incidence of PM, scab and sooty blotch
Ambstarking	Starking Delicious × Ambri-81	Tolerant to scab
Ambroyal	Starking Delicious × Ambri-84	-
Ambrich	Richared × Ambri-15	Tolerant to scab
Chaubattia Princess	Red Delicious × Early Shanbury	Early ripening variety
Chaubattia Anupam	Red Delicious × Early Shanbury	-
Intergeneric hybrid		
Pamapples	Pear × Apple	Developed by Ellis Marks (1952) in John Innes Centre

Features of varieties

- Ambri: longest shelf life and indigenous variety of India
- Red delicious is most popular variety in India
- Hazratbali (Benoni) earliest variety in Kashmir valley
- Commercial apple varieties grown in Jammu and Kashmir: Golden Delicious, Red Delicious, American Trel,
- Maharaj, Chemora and American Epirogue
- Elite apple cultivars for temperate regions : Red Fuji, Vance Delicious, Silver Spur, Spartan, Organ Spur and Granny smith (Green colour)
- Delicious group of apple varieties are self-incompatible and cross pollination in nature
- English group of apple varieties are self pollinated, act as a pollinizer for Delicious group of apples
- Diploid variety of apples are self fruitful whereas triploids are self-unfruitful
- Resistance to woolly apple aphid: *Malus hupehensis*
- Resistance to codling moth and powdery mildew: *Malus zumi*

- **Important rootstocks in apple:**

Category	Rootstocks	Features
Dwarfing	M9	Suitable for HDP
Semi-dwarf	M4, M7, M106, M24	Suitable for HDP, Resistant to wooly apple aphid
Semi-vigorous	MM-111 and MM-104	Tolerant to drought and Resistant to wooly apple aphid
Vigorous	Merton-793	Resistant to wooly apple aphid and collar rot
Ultra dwarf	M-27 (M13×M9)	Suitable for HDP

- ☆ MI series (Merton Immune) released from East Malling Research Station (EMRS), Kent, England
- ☆ MM series (Malling Merton) released from John Innes Institute, England
- ☆ MM series of rootstocks specifically bred for resistance to wooly apple aphid
- ☆ Most widely used dwarfing rootstock in apple: M-9
- ☆ East Malling Long Ashton (EMLA) series of rootstock is resistant to viruses
- ☆ East Malling Research Station is located at Kent in collaboration with John Innes Institute (JIH)
- ☆ Apple is a climacteric fruit
- ☆ Maturity indices: Starch index should be 1 to 2
- ☆ Storage temperature: -1.1 to 0°C 85-90% RH, storage period: 4-8months

Storage disorders:

- ✦ Internal browning: Browning streaks radiating into flesh from the core, susceptible variety: Yellow Newton
- ✦ Scald: mottling on greener surface of fruits-immature fruits are most susceptible
- ✦ Scab epidemic in Jammu and Kashmir-1772-73 and Himachal Pradesh-1778-79
- ✦ Zinc deficiency: Blind bud, little leaf
- ✦ Boron deficiency in apple: Hardy corky tissue, fruit cracking, blossom blast

Pest and diseases

- ☆ Woolly apple aphid (*Eriosoma langierum*) is the most devastating pest in the world
- ☆ Predator for woolly aphid: *Aphilenus mali*
- ☆ San Jose Scale (*Quadraspidiotus perniciosus*) is the most serious pest of apple
- ☆ Apple scab is caused by fungus *Venturia inaequalis*- Most serious disease in the world

2. Pear

1. **Pear**: *Pyrus communis*: Rosaceae: 2n=2X=34: Origin: Western China

- ✦ More tolerant to wet soils but less tolerant to drought than apple
- ✦ Italy is the largest producer of pear in the world
- ✦ Browning of pears is due to polygalacturonase enzyme activity
- ✦ Major acid: Malic acid
- ✦ Type of inflorescence: Corymbose
- ✦ All cultivated species under *Pyrus communis*
- ✦ Modern European cultivars are characterized by melting or buttery flesh,
- ✦ *P. pyrifolia* and *P.* × *bretschneideri* are characterized by finely grained and crisp flesh
- ✦ Grit cells presence mainly in skin and core
- ✦ Pear genome sequenced by China, 2012: Genome size: 512Mb, Sequenced species: *P.* × *bretschneideri* (Asiatic pear group)
- ✦ Most of pear cultivars require chilling 1200 hrs below 7°C
- ✦ Low chilling pear cultivars: 150 hrs below 7°C
- ✦ Chilling requirement of European pear: 1200-1500 hrs below 7°C

Important species:

Common name	Scientific name	Derived from/Uses
Common pear/French pear/English pear/European pear	*P. communis*	Commonly grown in the world
Japanese sand pear/Oriental Pear/Asian pear	*P. pyrifolia*	Grown in japan and china
Chinese/Sand Pear	*P. sinensis*	Commonly grown in North Indian plains
Wild Pear/Kainth/Mahal	*P. pashia*	Common rootstock in the Northern India
Snow pear (Perry pear)	*P. nivalis*	Suitable for perry preparation

Propagation and rootstock:

- ☆ Commercial clonal rootstock: clonal selections of quince
- ☆ Most commonly used clonal rootstock: Quince A

☆ Vigorous rootstock of pear: *Pyrus pashia*

☆ Commercial propagation method: T budding or tongue grafting

Quince

✦ Quince is monotypic genus

✦ *Cydonia oblonga:* Origin: South Eastern Europe and Asia minor

✦ Mostly used for standard dwarfing rootstock for pear

✦ Commercially propagation done by cuttings

☆ Graft incompatibility is overcome by double grafting with Old Home or Hardy varieties

☆ Pear and quince grafting associated with Graft incompatibility: Old Home is the best interstock for compatible scion

☆ Commonly used rootstock in the Southern India: Country pear (*Pyrus pyrifolia*)

☆ Planting time: June-July to October-November

☆ High density pear orchard: 1000-4000 trees/ha

☆ In India, Open centre system is commonly followed

☆ Training system: Modified central leader system

☆ Double working or double grafting is practised in pear

☆ Most of the pear varieties are self sterile (due to gametophytic self incompatibility)

☆ Most of the pear cultivars grown in hills are partially self-fruitful

Special varieties:

Specific features	Varieties
Introduction from Europe	Bartlett, Anjou, Kieffer
Low chilling varieties	Kieffer, Le-Conte, Patharnakh, Gola, Punjab Nectar
High chilling varieties	Anjou, Bartlett, Conference, Flemish Beauty
Soft fleshed selection	Red Blush, Punjab Gold, Punjab Nectar
Most popular varieties in North India	Nash, Patharnakh
Most popular varieties in temperate regions	Bartlett
Most popular variety in Tamil Nadu	Kieffer (popular in Kodaikanal hills)
Variety free from gritt cells	Flemish Beauty (Pollinizer variety)
Spontaneous mutation (Bud sports)	Starkrimson, Clapp's Favourite (Red coloured pear)
d colour and flavoured variety	Starkrimson Delicious

Hybrid	Prabhat: Sharbati × Florda Sun (Early maturing hybrid)
Interspecific hybrid	Le Conte and Kieffer (*P. communis* × *Pyrus serotina*)
Interstem cultivar	Old Home
Famous European varieties	Bartlett, Max Red Bartlett (Bud mutant of Bartlett)

☆ Bartlett or Williams or William Bartlett is the most popular variety all over the world

☆ Kieffer: Well adapted widely grown in India

☆ Red coloured pear varieties: Red Anjou from Anjou

☆ Punjab Agricultural University (PAU), Ludhiana: Punjab Gold, Punjab Nectar, Punjab Soft

Intergeneric sterile hybrids:

Sterile Hybrids	Parents
Mule	Troth Early Peach × Wild goose Plum
Kamdesa	Peach ×Sand Cherry
Pyronia	Pear × Quince

☆ Harvesting stage for canning and distant market: Fully mature but firm and green

Pest and diseases

☆ Pear psylla (*Cacopsylla* spp) is major pest

☆ Fire blight of pear (Most serious disease) is caused by bacteria (*Erwinia amylovora*)

☆ European pear is highly susceptible to fire blight disease

☆ Resistant to fire blight: *Pyrus calleryana*

☆ Pear leaf spot, caused by the fungus *Fabraea maculate*

☆ European pear scab: fungus *Venturia pirina*

☆ Pear decline is caused by phytoplasma, which is transmitted by pear psylla (*Cacopsylla* spp)

Physiological disorders

☆ Storage disorder: Core break down and scald

☆ Free from storage disorders: Anjou

☆ Boron deficiency: Corky tissue, calyx end rot and blossom blast

☆ Calcium deficiency: Black end and Cork spot

☆ Boron deficiency: Fruit cracking

☆ Core break down or brown heart is due to abnormal cool season

☆ Hard end of pear is due to unfavourable water conditions

☆ Pink end is due to abnormal cool season preceding harvest

3. Plums

3. **Plums** (*Prunus sp.*): Rosaceae: 2n=2X=32

- ☆ *Prunus* including all of the economically important crop species known as stone fruits almonds, apricots, cherries, peaches, and plums
- ☆ Base haploid chromosome number for *Prunus* is X = 8
- ☆ Commercially grown in Jammu and Kashmir, Himachal Pradesh
- ☆ World leading producer: China
- ☆ Plum fruit is sweet, juicy and it can be eaten fresh or used in jam-making
- ☆ Dried plums are known as prunes
- ☆ Plums and prunes are known for their laxative effect
- ☆ Plums contain more antioxidant than any other fruit
- ☆ The major cultivated plum species are European plum, *P. domestica* and Japanese plum *salacina*
- ☆ Commercial cultivated plums belongs to *Prunus domestica*
- ☆ Most of the varieties grown in India belongs to Japanese plum (*Prunus salicina*)
- ☆ Mature plum have dusty coating or wax coating due to glaucous appearance due to presence of epicuticular wax
- ☆ Alcoholic drink slivovitz (Plum brandy) is the national drink of Serbia (prepared from Serbian plum)
- ☆ The mei blossom (*Prunus mume*) traditional floral emblems of China
- ☆ High sugar content and suitable for drying without removal of the pit: Prunes group of Plum
- ☆ Leading prune variety: Stanley
- ☆ Famous plum breeder: Burbank, California, USA

Important plums groups:

Common Name	Scientific Name	Origin
European Plum	*Prunus domestica*	Europe
Damson Plum	*Prunus insititia*	Western Asia
Cherry or Myrobalan Plum	*Prunus cerasifera*	Western Asia and Central Asia
Japanese Plum	*Prunus salicina*	China
American Plum	*Prunus americana*	North America
Simon plum	*Prunus simoni*	North America

Chilling requirement:

- ✦ Japanese plum requires 700-1000 hrs below 7°C
- ✦ European plum requires 1000-1200 hrs below 7°C

- ☆ Commonly used and ideal method of propagation: Tongue grafting (February)
- ☆ Recommended clonal rootstocks for raising plum plants: Myrobalan B
- ☆ Dwarfing rootstock: *Prunus subordata*
- ☆ Planting time: December-January
- ☆ Training system: Open centre system-Oldest system
- ☆ Modified central system is most commonly followed in India
- ☆ Plum bears erratic flowering habit
- ☆ Japanese plums are mostly adaptable to open centre system
- ☆ Fruit thinning agents: DNOC, Ethephone, 3-CPA
- ☆ Japanese plum needs thinning (25-40% fruits)
- ☆ Self-fruitful varieties: 30% of flowers set fruits
- ☆ Heavy bearing habit
- ☆ Self-unfruitful varieties: 1.5% flowers set fruits
- ☆ Japanese plum varieties are mostly self unfruitful varieties and requires pollination

Varieties:

Special features	Varieties
Introduction	Santa Rosa, Sutlej Purple: Suitable for midhills of North Western Himalayas
European plum varieties	President, Victoria, Starking Delicious, Green Gag
Japanese plum varieties	Beauty, Santa Rosa, Mariposa
Subtropical plum varieties	Sultlej Purple, Kala Amritsari, Titron
Self fruitful varieties/pollinizer	Beauty, Santarosa, Mariposa
Self unfruitful varieties	Kelsey, Eldorado, Wickson, Larado and Farmosa
Popular varieties	Frontier, Santa Rosa

Interspecific hybridization:

Interspecific hybrids	Parents
Plumcot	Plum × Apricot
Plouts	Plum × Apricot × Plum
Apriums	Apricot × Plum × Apricot
Santa Rosa	*P. salicina* × *P. simoni or P. americana*

☆ Santa Rosa: Japanese plum hybrid
☆ Leading prune variety: Stanley
☆ Climacteric fruit
☆ Number of grades in plums: 3
☆ Fruits TSS at time of maturity: 12.5% Brix
☆ Fast track plum breeding started to reduce the juvenile period in temperate fruits
☆ Transgenic early continuous flowering (ECF) gene induce early flowering
☆ Major problem: Plumpox virus (PPV),
☆ Major problem in tropical cultivars: Sun burn

4. Peaches

4. **Peach**: *Prunus persica*: Rosaceae: 2n=2X=16: Origin: China
☆ Highly susceptible to water logging condition
☆ Peach is self-compatible in nature
☆ Peaches and nectarine are same species and same genus
☆ Among the temperate fruits, peach has lowest chilling requirement and earliest flowering
☆ Low chilling peach requires: <500 hrs of chilling
☆ Red blush skin colour is due to anthocyanins Nectarine (*Prunus persica* var. *nucipersica*) Smooth skinned peaches
☆ Nectarine is a fuzzless (smooth skinned) peach with strong flavour and aroma
☆ Nectarines is due to single dominant gene mutation in peach for fuzziness
☆ Nectarine cultivars are mostly preferred for table purpose
☆ Yellow colour of peach fruit is due to xanthophylls
☆ Predominant acid present in peach fruit: Malic acid
☆ Prunacin is the main principal glycoside present in the pulp
☆ Amygdalin is present in the peach seeds
☆ Peach seed oil content: 40-50%
☆ Type of fruit: Drupe
☆ *Prunus behmi* is a natural hybrid of Almond and Peach
☆ Yellow fleshed peaches are ideal for table and canning purpose
☆ For dehydration purpose: White fleshed peach

☆ Yellow fleshed peach varieties: Florida Sun, Shane-e-Punjab
☆ White fleshed peach varieties: Sharbati, Prabhat
☆ Commercially propagation method: Tongue or cleft grafting and T budding or ring budding
☆ Peaches requires regular and heavy pruning
☆ Best time of pruning time in North India: Mid winter (December to January)
☆ Pruning time for tropical region: Mid-December to January End
☆ Commonly using training system in hills: Vase or Open system
☆ Pruning intensity is most severe because fruiting occurs laterally on branches only on previous season's growth

Spacing:
- ✦ High density planting: 3 m × 3 m
- ✦ Tatura trellis system: 5 m × 1 m (2000 plants/ha)
- ✦ Meadow system: 2 m × 1 m (5000 plants/ha)

☆ To avoid spring frost, delaying bloom period: Spraying of GA_3 @ 200 ppm or Ethephon

Special varieties:

Specific features	Varieties
Nectarine cultivars	Nectared, Sun Grand, Sun Lite, Sun Red, Sun Rise, Sun Ripe
Mid season variety	Earligrande
Early ripening	Florida Prince
Low chilling varieties	Florda red, Sun Red, Sun Gold, Shane-e-Punjab, Sharbati, Saharanpur Prabhat
Male sterile variety	J.H.Hale, July Elberta, Halberta
Yellow fleshed variety	Florida Sun, Shane-e-Punjab
White fleshed variety	Sharbati, Prabhat
Nectarine variety	Sun Red

Special hybrids:

Natural hybrids:		
GF-557, GF-677	Peach × Almond	Widely used rootstocks for peach and almond
Inter specific hybrids:		
Myran	*Prunus helsiana* × Yunnan	Tolerant to drought and root knot nematode, *Armilaria*, *Verticillium* diseases

Marianna	*P. domestica* × *P. munsoniana*		Better rootstocks for heavy soil
Nemaguard	*P. persica* × *P. davididasa*		Widely used us a root-knot nematode resistant stock
Redhar	Halehaven × Kalhaven		-
Damas	*P. domestica* × *P. spinosa*		Better rootstocks for heavy soil
Recent hybrids:			
Regal		-	Resistance to cold and bacterial spot disease

- ☆ Recent new hybrids: Gala, Glory
- ☆ Sharbati: Developed through clonal selection
- ☆ Prabhat (Sharbati × Florida Sun)
- ☆ Commercial varieties cultivated in plains of Punjab: Florida, Florida Prince, Earlygrande
- ☆ Nematode resistant rootstock: Nemaguard, Nemared, Shalin and Yunnan
- ☆ Maturity indices: Calendar date, DFFB (Days from full bloom to maturity), freeness of pi
- ☆ Physiological disorder: Sunscald
- ☆ Important varieties: July Elberta, J.H. Hale (Self-sterile variety)

Pest and disease

- ☆ Peach leaf curl is caused by *Taphrina deformans* (fungus)
- ☆ Peach leaf curl aphid (*Brachycadus helichnsyi*) is the most serious pest of peach
- ☆ Peach short life syndrome (PSLS) is caused by ring nematode

Physiological disorders

- ☆ Physiological disorder: Splitting and gumming is due to prolonged dry period and sudden
- ☆ Splitting of fruits (at pit hardening stage) and gumming cause: Unknown or undetermined
- ☆ Major problem: Sun Scald

5. Cherries

5. **Cherry**: *Prunus avium:* Rosaceae 2n=2X=16: Origin: South East Europe and North West Asia
   - ☆ Sensitive to frost and waterlogging
   - ☆ Cherry have more calorific value than apple
   - ☆ Flavour of cherry: Methyl anthrinilate and methyl salicylate
   - ☆ Colouring compound present in cherry: Keracyanin chloride
   - ☆ World leading breeding of cherry: John Innes Horticultural Institution, Merton

Important species:

Common name	Scientific name	Uses
Sweet cherry	*Prunus avium*	Mostly used for table purpose
Sour cherry	*Prunus cerasus*	Tetraploid, Mostly used for canning or cooking
Duke cherry	*Prunus gudouini*	Interspecific hybrid

- ✦ Sour cherry is hybrid of *Prunus avium* × *Prunus fruticosa*
- ✦ Duke cherry: Sweet cherry (*Prunus avium*) × Sour cherry (*Prunus cerasus*)
- ✦ Cultivated hybrid ornamental Yoshino cherries in Japan (cherry blossom): *P.* × *yedoensis*
- ✦ Putative ancestor of cultivated sweet cherry: Mazzard

- ☆ Type of incompatibility: Gametophytic incompatibility
- ☆ Commercial propagation: Tongue (Whip) grafting
- ☆ Propagation time: February to March
- ☆ Most commonly used rootstock for sweet cherry in India: Paja (*Prunus cerasoides*)- Delayed incompatibility
- ☆ Common method of clonal rootstock multiplication: Mound or stool layering
- ☆ Other rootstocks: Wild bird cherry (*Prunus padus)* and Mahaleb (*Prunus mahaleb*)
- ☆ Ideal planting time: December to January
- ☆ Common adopted training system: Modified leader system
- ☆ Spacing: In rectangular system: Sour cherry: 10 m×14 m and sweet cherry: 7 m×10 m
- ☆ Sod culture is most important cultural operation in cherry also apple, pear
- ☆ Most commonly used sod crops: Rye, vetch, buckwheat, oats and millets
- ☆ Common disorder in cherry: Sunscald
  - ✦ Cherry wine: Kirschwasser
  - ✦ Cherry cordial: Maraschinos
- ☆ Most common deficiency: Abnormal reduction in fruit size: Zinc and Interveinal chlorosis is due to Mg

Varieties:

Sweet cherries	Sour cherries	Duke cherries
Geans or Heart group	**Amarelles group**	Ronald's Duke
i. Light coloured	Early Richmond	Royal Duke
Victor, Chico Beauty, Sue	Montmorency	May Duke
ii. Dark coloured	**Morellous group**	Arch Duke
Waterloo, Ebony, Lambert	Flemish Red	
Bigarreaous group	English Morello	
i. Light coloured	Louis Phillipe	
Napoleon, Yellow Spanish		
ii. Dark coloured		
Black Heart, Tradescant's Heart		

Specific features of varieties:

- ☆ Most of the cherry varieties are self sterile, it needs cross pollination
- ☆ Most of the sour cherry varieties are self-compatible
- ☆ Mahaleb is also known as St. Lucie Cherry
- ☆ Clonal rootstocks: Colt and Mazzard F-12/1
- ☆ Universal donor varieties: Stella, Vista, Vic, Seneca and Vega
- ☆ Sweet cherry varieties: Royal Ann (Napoleon) is most popular variety
- ☆ Self fruitful varieties: Early Richmond and Montmorency
- ☆ Resistant to fruit cracking: Sam, Sue, Windsor, Victor

6. Strawberry

6. **Strawberry**: *Fragaria × ananassa:* Rosaceae, X=7, 2n=8X=56, Octoploid: Origin: France
   - ☆ Artificial man-made hybrid: Garden Strawberry *Fragaria chilonensis* × *Fragaria virginiana* (Diploid species) first bred in Europe in the early 18th century via an accidental cross
   - ☆ Monoecious, short day and quick growing fruit plant
   - ☆ Low growing perennial and shallow rooted crop
   - ☆ Fruit crop for kitchen garden
   - ☆ Accessory fruit crop
   - ☆ The name "straw" berry comes from the practice of the farmers making mulching over the plants of strawberries by using straw

- ☆ Unique place among cultivated berry fruits
- ☆ Fruit of strawberry is complete fruit with 98% of edible portions
- ☆ Strawberries are rich in vitamin C, ascorbic acid and ellagic acid
- ☆ Edible portion: Succulent thalamus
- ☆ Spring frost is a major limiting factor in early strawberry production
- ☆ Major blooming season: December
- ☆ Frost injury symptoms: leaf bronzing, blackening of flowers and fruit malformation
- ☆ Responsible for flavour of strawberry fruits: Ethyl esters *i.e.*, Ethyl butanoate and ethyl hexanoate
- ☆ Indian wild strawberry: *Fragaria vesca*
- ☆ Hermaphroditism is much more common in *Fragaria chilonensis*
- ☆ 1st fruit crop micropropagation studied
- ☆ Strawberry genome sequenced in 2011 (*Fragaria vesca*, 2n=14): Genome size: 250Mb
- ☆ Flowers are borne in small cluster and white in colour
- ☆ Type of inflorescence: Dichotomic raceme
- ☆ Type of fruit: Etaerio of achens
- ☆ Type of pollination: Both self and cross
- ☆ Major pollinator: Honey bees

Varieties: Premier, Red Coat, Local Jeolikot, Dilpasand, Bangalore, Florida-90, Katrain Sweet, Blackmore, Pusa Early Dwarf, Phenomenal, Majestic, Sujatha, Labella

- ☆ Pajaro: Most successful under summer system and tolerant to viruses
- ☆ Most popular acceptable variety in North Indian plains: **Chandler**: Resistant to viruses, resistant to physical damages caused by rain and suitable for fresh market and processing

Special varieties:

Specific features	Varieties
Hybrid: Arking	Cardinal × Ark-5431
Suitable for meridional conditions	Tioga
Suitable varieties for Septentrional culture	Senga Sengan, Redgaunlet and Gorella
Day neutral variety	Selva, Fern, Muir, Hecker, Tristar and Trileute
Day neutral and offseason variety	Selva
Ideal varieties for processing	Midway, Midland, Hood, Redchief and Beauty
Suitable varieties for ice cream making	Olympus, Hood and Shuksan (High flavour and bright red colour)

- ☆ All the cultivated varieties of strawberries are allo-octoploid
- ☆ Early bearer cultivars are day neutral types
- ☆ Commercial propagation: Runners
- ☆ Induction of runners formation: IBA @ 100ppm
- ☆ Ideal time of planting runners or crown in hilly regions: September to October
- ☆ There are 4 training system, among them matted row system is commercially follow India
- ☆ Strawberry is a heavy feeder crop
- ☆ Mulching is most important cultural operation in strawberry especially June,, to ma temperature above 15°C
- ☆ Harvesting stage: ½ to ¾th of skin develops colour
- ☆ Physiological disorder: Albinism- Lack of fruit colour
- ☆ Serious disease of cultivated strawberry: Grey mould or Fruit rot (*Botrytis cinerea*)

7. Kiwi Fruit

7. **Chinese gooseberry/China's miracle fruit/Horticultural wonder of New Zealand**

National symbol of New Zealand: *Actinidia deliciosa*: Actinidiaceae: 2n=8X=58: X=29: Ori China

- ☆ Deciduous, dioecious vine fruit crop
- ☆ Flowers borne: Current season shoots
- ☆ Leading producer of kiwi: Italy
- ☆ Flower colour: Creamy white to yellowish
- ☆ Type of fruit: Berry
- ☆ Growth pattern of fruit: Triploid growth
- ☆ Total phenotypic gender expression: 6
- ☆ Gender change due to bud mutation in a mature male vine
- ☆ Cold tolerant species: *Actinidia arguata*
- ☆ Commercial propagation: Stem cuttings- Soft wood cuttings
- ☆ Flowering time: Last week of April to 3rd week of May
- ☆ Storage rot is caused by *Botrytis cinerea*: Major disease during storage

Varieties:

Varieties	Specific features
Tomuri, Motus, Matua	Staminate cultivars/Pollinizer variety
Allison, Monty	Pistillate cultivars
Abott	Early flowering cultivar
Hayward	Shy bearing and late maturing cultivar and more suitable to high hill
Bruno	Rich source of vitamin-C variety

8. Apricot

8. **Coppery fruit/Apricot**: *Prunus armeniana:* Rosaceae: Origin: North Eastern China

- ☆ Drought resistant, salt tolerant hardy temperate fruit crop
- ☆ Apricot is a semi dried fruit
- ☆ Apricot tolerant to dry atmosphere
- ☆ Highly perishable fruit, semi dried fruit
- ☆ Vitamin-A: 3600 IU and Thiamine: 217 mg/100g
- ☆ Wild apricot or zardalu is originated from India
- ☆ Type of fruit: Drupe
- ☆ Edible portion: Mesocarp and Endocarp
- ☆ Popular training system: Open vase system
- ☆ Apricot bears on spurs and laterally on 1 year old shoots
- ☆ Apricot spurs life: 3-4 years
- ☆ Ideal thinning agent: NAA @ 25-50 ppm 20 days after fruit set
- ☆ Commerical propagation: T-budding or shield budding
- ☆ Training system: Modified central leader
- ☆ Maturity time: May to June
- ☆ Ideal stage for freezing, canning and drying: Fully ripe fruits

Varieties	Parents	Specific features
Chaubattia Alankar	Kaishu × Charmagz	Low chilling and Early ripening
Chaubattia Madhu	Turkey × Charmagz	Early ripening
Chaubattia Kesri	St. Ambrois e× Charmagz	Mid season variety

☆ Low chilling subtropical varieties: New Castle, Early Shipley, St. Ambroise, Kaisha

☆ Important varieties: New Castle, Kaisha, Charmagaz, Nugget, Moorpark

IV. NUTS

9. Almond

9. **Almond**: *Prunus amygdalus*: Rosaceae: 2n=2X=16: Origin: Central Asia

☆ Important temperate nut fruit

☆ Bitterness in almond due to presence of amygdalin content

☆ Among temperate fruits, almond requires very specific climate

☆ Chilling requirement: 800 hrs

☆ Type of fruit: Drupe

☆ Type of incompatibility: Gametophytic incompatibility

☆ Edible portion: Kernel or Cotyledon

☆ Rootstock: Behmi *(Prunus nira)*

☆ Shield budding time: July to August

☆ Training system: Central modified leader system

☆ Recommended beehives for efficient pollination: 5-8 beehives

☆ Maturity indices: Change colour from green to yellowish with cracks

☆ Dehulling term related to 'almond'

Varieties: IXL, Jordanolo, Merced, Non-Pareil (Leading cultivar), Texas, Drake, Peerless

Breeding methods	Varieties/Hybrids	Special features
Most popular variety	Neplus-Ultra	-
Introduced varieties	Makhdoom, Parbat, Waris, Shalimar, Pranyaj	-
Hybridization	Sloh (Peach×Almond)	Self fertile
Mutant variety	Supernova	Late flowering and self compatible variety

10. Walnut

10. **King of nut/Walnut**: *Juglans regia*: Juglandaceae: 2n=32: Origin: Central Asia

☆ Monoecious, temperate nut fruit

☆ Most valuable exchange earning nut crop

☆ Walnut is rich source of fat

☆ USA is the leading producer of walnut

☆ Jammu and Kashmir is the largest walnut producing state of India

☆ Male are borne terminally and female flowers laterally

☆ Type of pollination: Cross

☆ Mode of pollination: Wind

☆ Paradox is a rootstock derived from *Juglans hindsi* × *Juglans nigra*

☆ **Varieties**: Govind, Roopa, Karan

☆ Interspecific hybrid: Walnut and Royal

☆ Ideal training system: Modified central leader

☆ Harvesting: PTB stage (Packing tissue turn brown)

☆ Reduction of walnut hull dehiscence: Ethephon @ 2000 ppm

☆ Blank nut is due to hot summer with low humidify

11. Peacanut

11. **Queen of nut/Pecanut**: *Carya illinoensis*: Juglandaceae: 2n=2X=32

☆ Heterodichogamy is observed in pecanut

☆ Type of pollination: Cross

☆ Male and female flowers borne in mixed flower bud

☆ Major problem: Biennial bearing

G. Arid and Semiarid Zone Fruit Crops

1. Ber
2. Aonla
3. Annonaceous fruits
4. Pomegranate
5. Date palm
6. Fig
7. Bael
8. Phalsa
9. Jamun
10. Karonda
11. West Indian Cherry
12. Carambola

1. BER

1. **King of Arid fruits/ Poor man's fruit/Summer deciduous fruit**: 2n=48: *Zyzyphus mauritiana* Rhamnaceae: Origin: Indo-China or India
   - ☆ Hardy salt tolerant fruit
   - ☆ Ideal tree for arid and semi arid culture
   - ☆ Ber fruits are higher calorific value and vitamin-C than orange
   - ☆ Sylleptic branching pattern is observed in ber
   - ☆ Pleoanthic in flowering habit
   - ☆ Flower colour: Greenish to yellow
   - ☆ Type of inflorescence: Axillary cymes emerging from mature and current season's growth
   - ☆ Ber breeding hampered due to high heterozygosity
   - ☆ Fruit set affected by: cross incompatibility and self-sterility

Commercially cultivated species:

Common name	Botanical name	Specific features
Indian ber	*Zyzyphus mauritiana* (Polyploidy)	Evergreen, Spreading habit
Chinese ber	*Zyzyphus jujuba*	Deciduous, Upright, Highly resistant to frost
-	*Z. nummularia*	Dwarfing rootstock
-	*Z. rotundifolia*	Commercially used rootstock for arid regions
		Resistant to Fruit fly

Varieties:
- ☆ Gola, Seb, Kaithali, Mehrun, Darakhi, Banarasi, Dandan, Elaichi
- ☆ Gola: Early variety (end of December) and tolerant to saline soils
- ☆ Mid season: Kaithali, Mundia
- ☆ Late variety: Umran
- ☆ Katta Paul: Apple's variety- fruit resembles in shape and colour with apple
- ☆ Tikadi (tetraploid): commercial variety of *Z. rotundifolia*

Recent new variety:

Central Institute of Arid Horticulture, Bikaner, Rajasthan		
Thar Sevika	Seb × Katha	
Thar Bhubraj	Selection from Bhusavar area of Bharatpur	
Goma Kirti	Clonal selection from Umran	Early maturing, high yielding variety

- ☆ Seed dormancy due to hard endocarp
- ☆ Overcoming seed dormancy: breaking endocarp or soaking of seeds at GA_3 500 PPM for 24 hours
- ☆ Commercially propagation: I or T or Shield budding-Easier to adopt and convenient
- ☆ Highly suitable for arid conditions: *In-situ* budding (July to September)
- ☆ Best time of planting: July to September
- ☆ Type of training system: Modified leader system

Pruning
- Ber requires heavy pruning every year
- Flowers bore at current season growth
- Pruning time for north Indian condition: mid- to end of May
- Spacing for HDP: 5m × 5m
- Flowering time: August or September to November
- Non-climacteric fruit
- Mature time:(March)150-175 days after flowering
- Harvesting period: November to March
- Average yield: 80 to 200kg/tree

Pest and diseases:
- ☆ Fruit fly (*Carpomiya vesuviana*) is the major pest of ber. Mainly infest at pea stage
- ☆ Ber fruit borer (*Meridarches scyrodes*)
- ☆ Powdery mildew (*Oidium sp.*) is the major disease of ber

2. AONLA

2. **Amla/ Fruit of the 21st century /Indian Goose Berry/Amritphal fruit/Scared tree:** *Emblica officinalis: Euphorbiaceae:* 2n=2X=28: Origin: Central to Southern India

- ☆ Evergreen in tropics whereas deciduous in subtropics
- ☆ Subtropical fruit plant and prefers dry subtropical climate
- ☆ Amla is a hardy, drought resistant fruit tree.
- ☆ Its ability to withstand water stagnation and frost
- ☆ More popular as backyard fruit throughout the country
- ☆ Very rich in Vitamin-C (600 mg/100g) maximum in mature fruits
- ☆ Uses: Preparation of hair dyes and hair oils
- ☆ Only astringent fruit is used for ayurvedic medicine
- ☆ Large sized graded used for candy and preserve
- ☆ Medicinal value: Vitality restorer
- ☆ Small sized grades used for *chavanprash* and *trifla* preparations
- ☆ Mature tree can tolerate freezing temperature as well as high temperature: 46°C
- ☆ Ideal plant for arid and semi arid condition due to deep root system, reduced foliage and dormancy of fertilized fruitlets
- ☆ Ideal plant amicable for 2 to 3 tier cropping system
- ☆ Amla contains 6 seeds/fruit
- ☆ Phyllanthoid branching habit: Determinate and indeterminate shoots
- ☆ **Related species**:
  - ✦ Star gooseberry or Otaheite gooseberry: *Phyllanthus acidus* 2n=2X=28
  - ✦ It bears fruits throughout the year in South India
- ☆ Two prominent cropping season : July-August and April-May
- ☆ Type of fruit: Capsular drupaceous fruit
- ☆ Type of inflorescence: Racemose
- ☆ Edible portion: Mesocarp and Endocarp
- ☆ Flowers are borne in the axils of the leaves on determinate shoots

Varieties:

Varieties	Breeding methods	Specific features
Early maturing (Mid-Oct to Mid-Nov)		
Banarasi		Early maturing, shy bearing, prone to heavy dropping of fruits
NA-5 (Krishna)	Seedling selection from Banarasi	**Big fruited variety**
NA-9	Seedling selection from Banarasi	Suitable for preserve and candy making
N-10 (Balwant)	Seedling selection from Banarasi	Fruits skin yellowish with pink tinge
Mid season: (Mid-Nov to Mid-Dec)		
Francis (Hathi Jhool)		Highly susceptible to necrosis
NA-4 (Kanchan)	Seedling selection from Chakaiya	Preferred for pulp extraction industries
NA-6 (Amrit)	Seedling selection from Chakaiya	Free from fruit necrosis, lowest sex ratio
NA-7 (Neelum)	Seedling selection from Francis	Ideal for commercial cultivation , Free from necrosis, Ideal variety for preparation of variety of products
Late maturing: (Mid-Dec to Mid-Jan)		
Chakaiya		Alternate bearer, Ideal for making pickles
Bhwanisagar (BRS-1)	Selection from "Thimban"	
Central Institute for Arid Horticulture, Bikaner, Rajasthan		
Goma Aishwarya	Clonal selection of NA-7	Early variety, Drought tolerant

- ☆ NA-4, NA-6, NA-8: Selection from Chakaiya
- ☆ NA-5, NA-9, NA-10: Selection from Banarasi
- ☆ Resistant to fruit necrosis: NA-6, NA-7, Chakaiya
- ☆ Limb breakage is major problem NA-7
- ☆ NA 7 used as a pollinizer fruit yield increased
- ☆ Unfruitfulness is a major problem
- ☆ Seed germination is enhanced by soaking of seeds by GA3 @ 500 ppm in 24hrs
- ☆ Commercial and more efficient propagation: Patch budding (Highly successful)
- ☆ Budding time: mid-May to mid- August
- ☆ Planting time: February to March
- ☆ For rejuvenation of old orchards preferred budding: T-budding

☆ Flowering to fruiting: 8 months
☆ Training: Single stem system (upto 1m height)
☆ Prefers planting system: Square
☆ Recent problem: Self incompatibility mechanism the non-bearing condition of fruit trees
☆ Type of pollination: Cross
☆ Mode of pollination: Wind
☆ Pruning: Removal of 50% of the erect growing shoots
☆ **Top working**
- Removal of old, aged and current unreproductive trees
- is done for rejuvenate the inferior variety or unproductive trees

☆ **Rejuvenation:**
- Removal of dense, old and unreproductive tree (senile orchard)
- It involves heading back (Topping) of branches
- Rejuvenation time period: 10-12years for old orchard
- It done a month of December-January

☆ Shoot thinning is done at May-June
☆ Type of irrigation: Basin system
☆ Harvesting time: December-February
☆ Maturity stage: Change seed colour from creamy white to brown
☆ Number of grades in Aonla: 3
☆ Economic yield starts at 4-5 years after planting
☆ Yield: 100-150kg/tree
☆ Internal necrosis is physiological disorder- Browning of Mesocarp and endocarp
☆ Francis is highly suceptible for necrosis followed by Banarasi

Pest and diseases:
☆ Rust (*Ravenelia emblicae*): Major disease of aonla growing regions
☆ Bark-eating caterpillar: (*Indarbela tetraonis*): Major pest of aonla

3. ANNONACEOUS FRUITS

3. **Custard Apple/Fruit of poor people/Evening flower scent bearing fruit crop**: *Annona squamosa*: Annonaceae: 2n=2X=14: Origin: Tropical America
☆ Tropical plant
☆ Sensitive to frost
☆ Custard apple is woody and semi-deciduous shrub or tree

☆ Flowering occurs singly or rarely in clusters mostly on current seasons growth
☆ Annona fruits are formed by fusion of pistil and receptacle
☆ Type of fruit: Large fleshy aggregate fruit
☆ Edible portion: Pericarp
☆ Type of pollination: Cross
☆ Mode of pollination: Wind (Aneomophilous)
☆ Artificial pollination (Hand pollination) recommended to get good fruit set
☆ Dichogamy- Protogyny is observed in *Annona* except *Annona muricata* (Protandry)
☆ Annona seedless is due to ovule sterility
☆ Among annonaceous fruits, custard apple is the most favourite in India
☆ Among the annonaceous the largest annona fruit bearing species: *Annona muricata*

Important annona species:

Common name	Botanical name	Specific features
Sitaphal/Custard apple/Sweet sop/sugar apple/Sharifa/Atakatal	*Annona squamosa*	Common/widely cultivated species in India
Sour sop/ Ramphal /Prickly custard apple /Mundla Sitaphal	*Annona muricata*	Moist humid condition, evergreen tree, heart shaped fruit, largest annona in the world
Atemoya/Prithviphalambu/Lakhshamanphal	*Annona atemoya* (*A. squamosa* × *A. cherimola*)	-
Cherimoya/Cherimoyer/ Hanumaanphal	*Annona* cherimola	Subtropical climate in tropics-Mostly grown in Assam and South Indian hills
Bullock's heart/Bull's heart/West Indian custard apple	*Annona reticulata*	More common in South India, Late season crop
Pond apple	*Annona glabra*	Drought tolerance and coloured flesh
Illama	*Annona diversifolia*	Fruit pulp like apricot flavour

Cultivars:
☆ Balnagar, Barbados, Mammoth, Israel hybrids, Red Sitapal, Washington, British Guinea, Mahaboobnagar, Kakarlapahad, Local Sitaphal, Washington, Saharanpur Local

Varieties:

- ☆ APK(Ca)-1: Clonal selection from Courtallam in Tamil Nadu: Drought tolerant and suitable for arid tracts of Tamil Nadu
- ☆ Artificial interspecific hybrid: Arka Sahan (Island Gem (Atemoya) × Mammoth (Custard apple), developed by Jalikop, 1997.
- ☆ *A. atemoya*: is a natural hybrid
- ☆ Pond apple: tetraploid species
- ☆ *Annona reticulata* is a good rootstock for *Annona squamosa* and *Annona cherimola*
- ☆ Spacing: 5m × 5m
- ☆ Seed viability: 3-4 years
- ☆ Planting system: Square or triangular system is most suitable
- ☆ Climacteric fruit
- ☆ Harvesting stage for long distance market: Firm
- ☆ Training system: Single stem
- ☆ Hand pollination is practiced to enhance the fruit set
- ☆ Harvesting stage: changing fruit colour into light green and development of yellowish white into tubercles
- ☆ Peak period of harvesting: October-November
- ☆ Annonas climacteric fruits
- ☆ Centrifugal process is developed by CFTRI for separation of gritty portion from pulp of custard apple

Pest and diseases:

- ☆ Fruit rot is caused by *Phytophthora citrophthora* and *P. nicotiana*- Major disease of custard apple
- ☆ Most destructive pest in custard apple: Mealy bug *(Planococcus pacificus)*

Physiological disorders:

- Stone fruits-remain fruits turn brown, become hard is major physiological disorder
- Woodiness: presence of seed pockets and gritty lumps in flesh
- Brown pulp: discolouration of pulp
- Tree decline caused by water stagnation
- Poor fruit set is problem in custard apple due to external and internal factors like dichogamy mechanism

4. POMEGRANATE

4. **Pomegranate /Fruit of paradise/Fruit of love/Anaar/National fruit of Iran**: *Punica granatum*-Punicaceae: 2n=2X=16: Origin: South West Asia- Iran (Persia)

- ☆ Pomegranate fruit is symbol of abundance and prosperity
- ☆ Fruit juice cool, refreshing and valued for its medicinal properties
- ☆ Winter hardy and highly drought tolerant shrub
- ☆ Most of the pomegranate varieties are deciduous trees
- ☆ Pomegranate is a Latin name of the fruit, which means ''grainy apple''
- ☆ Excellent choice crop for arid and semi-arid conditions of India
- ☆ First five fruit crops (date palm, fig, olive, grape and pomegranate) to be domesticated by mankind
- ☆ Red colour in aril and skin due to presence of anthocyanin
- ☆ Dried seeds with pulp is known as 'anar dana': Widely used as condiment: Prepared from sour type of wild pomegranate or daru
- ☆ Daru commonly found in Himalayan region: Long productive cycle and resistant to bacterial blight
- ☆ Anardana: Acidulant product used in souring and culinary preparations (Condiment)
- ☆ Indian local product Anar rub (TSS: 70-75°B): Used as sauce- Prepared from juice
- ☆ Fruit juice of pomegranate is valued medicinal properties for leprosy patients
- ☆ Evergreen cultivars also available in India especially (Rajasthan and south India)
- ☆ The nearly round fruit is crowned by the prominent calyx
- ☆ Edible part: aril
- ☆ Seedlessness in pomegranate: Lack of lignifications of testa
- ☆ Leading pomegranate producing states: MH>Karnataka>Gujarat
- ☆ Maharashtra is the leading state about 68.7 per cent of the area under pomegranate
- ☆ Evergreen cultivars in southern India, flowering season was observed in three periods: June, October, and March
- ☆ India is one of the largest producers of pomegranate in the world
- ☆ Major pomegranate exporting countries: Turkey
- ☆ India is the only country in the world where pomegranate is available throughout the year (January -December)
- ☆ It is cultivated in 3 seasons (Ambia bahar, Mrig bahar and hasth bahar) in Deccan plateau of India
- ☆ Leading state in India for pomegranate cultivation: Maharashtra
- ☆ National Research Centre for Pomegranate (NRCP), Kesaon, Solapur, Maharashtra: Established in 2005

☆ Pomegranate taste is due to citric acid
☆ All parts of the plant contains tannin
☆ Flowers has 2 types: Male (bell shape), Hermaphrodite (vase shape)
☆ Flower colour: orange-red to deep red
☆ Fruit type: Balusta (Fleshy berry.)
☆ Type of inflorescence: Hyphanthodium
☆ Type of pollination: Often cross pollination
☆ Predominant pollination: Cross pollination (due to heterostyly mechanism)
☆ Main pollinator agent: Honey bees
☆ Hermaphrodite flowers usually homostlyous or pin eyed and male flowers are thrum eyed
☆ Fruits are borne terminally on short spurs from mature shoots
☆ Common method of propagation: Hard wood cuttings
☆ Wild pomegranate: (*Punica protopunica*) is resistant to diseases: Used as a rootstock
☆ Species most suitable for pot plant production: Dwarf pomegranate (*Punica granatum* var. *nana*)
☆ Double Flower, an ornamental variety which bears only flowers (2n=18)
☆ Best planting time: February
☆ Training system: Multiple system is most prevalent in India

Crop regulation:

☆ 3 distinct flowering season: Subtropical Central and Western India
- ✦ Ambe Bahar: January to February flowering- Most common favoured by farmers, practised in high rainfall and humid areas.
- ✦ Mrig Bahar: June to July flowering, preferred in dry areas
- ✦ Hasth Bahar: September to October flowering

☆ Behaviour: Under tropical condition evergreen and subtropical condition. deciduous
☆ Bahar treatment or flower regulation is followed in pomegranate for higher productivity
☆ Mrig Bahar is preferred in arid regions
☆ Best quality fruits are produced in cool winters and hot dry summers

Ornamental pomegranate type:

1. Double flower type Ornamental part: Modification of stamens into petals look like rose flower
2. Nana or dwarf type: Bonsai pomegranate- Exclusively for ornamental purpose

Popular cultivars: Dholka, Alandi or Vadki, Kabul, Jodhpur local, Bedana Seedless, Kandhari, Red, Paper shell, Poona, Spanish Ruby, Vellodu

Varieties	Breeding methods	Specific features
Ganesh (GBG-1)	Selection from Alandi	Very soft seeded, well known cultivar
Bhagwa (Kesar)	Ganesh × Red Gul Shah Red	Popular variety, soft seeded variety
Mridula (Arkta)	Ganesh × Red Gul Shah Red	Blood red aril and soft seeded,
Jyothi (GKVK-1)	Selection from mixed seedling population of Bassein Seedless and Dholka	
CO-1		Higher pulp and sweet taste
YCD-1		Easily peelable rind: Suitable for subtropical hills
Ruby	(Ganesh × Kabul) ×Yercaud	Dark red aril and soft seeded
Shirin Anar		Resistant to bacterial leaf spot
Amlidana	F_1 hybrid from Ganesh Nana	Most suitable for anardana purpose
Sverkhrannil		Early and small soft seeded variety
Phule Arakta	Ganesh × Gul-e-Shah Red	Dark red aril
Goma Khatta	-	suitable for anardana purpose
Hyti		Red arils
P-23, G-137	Clonal selections from Ganesh variety	

Specific purpose:

☆ Ganesh: leading, most popular variety
☆ Attractive skin and aril colour: Bhagawa and Phule Arakta
☆ Bhagwa: leading variety in Maharashtra
☆ Bhagwa has done really well in farmers' fields compared to other varieties
☆ Tetraploidy variety: China
☆ Dholka, Ganesh, Kandhari, Muscat White and Patiala varieties have 2n=16
☆ Among the local types Jodhpur Red has maximum aril percentage
☆ Mridula, Bhagwa and Ganesh are evergreen cultivars.
☆ Export varieties to Europe (red skin, red aril, soft seeded) : Bhagwa, Mridula

☆ Tolerant/ resistant to fruit cracking: Appuli, Burachni and Francis
☆ Cracking tolerant varieties: Bedna, Bosek, Khog, Jalore Seedless
☆ Non-climacteric fruit
☆ Fruits ready for harvest: 120-130 days after fruits set
☆ Harvesting stage: Colour change to Yellowish red
☆ 12A grades is preferred in Northern and Southern India

Pest and diseases:

☆ Pomegranate (*Anar*) butterfly or fruit borer (*Virachola isocrates*) Serious pest all over India
☆ Bacterial blight (*Xanthomonas oxonopodis* pv. *punicae*) is serious problem in Maharashtra from 2007
☆ Wilt: complex phenomenon of infection by *Ceratocystis fimbriata*

Physiological disorders:

☆ Internal break down/Blackening of arils: Disintegration of arils in matured fruits is serious malady
☆ Internal break down is more in ambe bahar
☆ Fruit cracking of pomegranate is due to deficiency of
  - Calcium, boron and potash
  - Soil moisture imbalance
  - Sudden fluctuation of day and night temperature
☆ Sensitive to soil moisture fluctuation causing fruit cracking which is serious problem
☆ High incidence of fruit cracking: Spring crop (63%): January to June
☆ Mrig bahar is more prone to cracking
☆ Hardening peels is due to prolonged drought condition

5. DATEPALM

5. **Datepalm/Head in fire and foot in water crop/Tree of life**: *Phoenix dactylifera*: Palmae: 2n = 26: Origin: Mediterranean region or Persian Gulf
☆ Monocotyledonous, unbranched stem tree
☆ Dioecious fruit crop
☆ It is a highly nutritious fruit
☆ 1kg fully ripe fresh dates provide approximately 3150 calories
☆ Date palm tolerate high soil salinity pH 9-10
☆ Ideal mean temperature for flowering and ripening of fruits: 25-29°C
☆ Date palm should be grown, an Arab says "foot in running water and its head in the fire of the sky"

☆ Suitable area for cultivation: Prolonged hot dry summer, moderate winter, rain free period during ripening
☆ Base temperature for summation of heat units for date palm: 10°C
☆ Required heat units: 3300
☆ Type of inflorescence: Spadix
☆ Type of fruit: One seeded berry
☆ Type of pollination: Highly cross pollinated
☆ Commercial propagation: Offshoots (Ideal weight 8-10kg is preferred)
☆ Off-shoots separation time: February to March and August to September
☆ Best time of planting: Rainy season (July -September)
☆ 2-3 male plants are enough for pollinating 100 female plants
  - Closed related species found in India: *Phoenix sylvestris:* Source for jaggary and a drink-toddy
  - Wild species found in Western and Eastern ghats hills: *Phoenix humilis*
☆ Suitable for commercial cultivation in India: Northern-Western regions

Varieties:

✦ Shamran (Sayer), Khadraway, Medjool, Hayany, Barhee, Zahidi (Mid-season variety), Khalas
✦ Early ripening variety: Halawy (Most popular variety in india) and Khunezi
✦ **Soft varieties**: Barhee, Halawy (Tolerant to rains, early soft variety)
✦ **Semi-dry or Dry** (also known as Cane sugar dates): Dayari ; Dry: Thoory

☆ 1 male flower is sufficient to for 40-50 females
☆ Average yield: Rainfed condition: 40-50kg/palm; Irrigated condition: 200kg/palm
☆ Dry dates (*Chhuharas*) and Soft dates (*Khajoor*)
☆ Metaxenia is a common problem in Datepalm
☆ Leaf pruning is the common pruning method- June is the best season for leaf pruning
☆ About 75-100 leaves are found optimum good yield
☆ Effective thinning agent: Ethephon
☆ For early ripening: Ethrel@500-1000ppm
☆ In India date harvest at Doka stage (70-80% moisture)
☆ Soft dates harvested at *pind* stage
☆ Doka fruits are useful for processing of *Chhuhara*
☆ For fresh eating dates are harvested or preferred at dang (translucent and starts softening) stage
☆ For fresh consumption dates are harvested at peak of doka (colour turns green to yellow) stage
☆ For storage purpose dates are harvested at tamar or pind (attain full mature) stage
☆ Post-harvest losses mainly due to rain about 32-40%

6. FIG

6. **Fig/Forbidden fruit**: *Ficus carica:* Moraceae: 2n=36: Origin: Western Asia
   - ☆ Wholesome, nutritious and delicious fruits
   - ☆ Fig fruit extremely perishable fruits
   - ☆ Total sugar content of fresh fruit: 16% while dried one: 52%
   - ☆ Fruits have high calorific value: 269
   - ☆ Medicinal value: Laxative properties
   - ☆ Large shrub or deciduous tree
   - ☆ Subtropical deciduous fruit plant
   - ☆ Fairly drought tolerant crop
   - ☆ Fig tree denotes "peace and prosperity"
   - ☆ Rich in protein and digesting enzymes "Ficin"
   - ☆ Predominant acid in fig: Citric acid
   - ☆ Fig is gynodioecious species
   - ☆ Type of fruit: Syconium (Multiple fruit)
   - ☆ Type of inflorescence: Hyphanthodium
   - ☆ Symbiotic relationship with insects for fruit setting
   - ☆ Type of pollination: Cross pollination is known as "Caprification"
   - ☆ Pollination agent: Fig wasp (*Blastophaga psenes*)
   - ☆ Fig wasp mostly prefers for harbour in Capri fig
   - ☆ Commercial propagation: Hard wood cuttings (20-30 cm long)
   - ☆ *Ficus glomerata* rootstock is used for resistance to root knot nematode
   - ☆ Based on pollination pattern and sex of flower: 4 types of fig
   - ☆ San Pedro Fig completely parthenocarpy, first crop (breba crop)
   - ☆ Smyrna Fig: commercially grown in USA and Europe
   - ☆ Common fig: commercially grown in india
   - ☆ Commercial varieties in south india: Pune fig, Marseilles
   - ☆ Suitable for drying: Smyrna (large white fig)
   - ☆ Adriatic fig (pink flesh): drying purpose
   - ☆ Suitable for Canning: Kadota

Varieties: Pune Fig, Black Ischia, Brown Turkey, Bangalore, Marseilles

Group	Varieties
Common/Edible/Adriatic fig (Mostly grown in India)	Conardia, Poona, Kadota, Brown, Turkey, Mission
Smyrna Fig	Calimyrna, Taranimt and Zidi
San Pedro Fig	San Pedro, King, Gentile and Lampeiria
Wild/Capri Fig/Male/Goat fig (Used as pollinizer)	Samson, Stanford, Brawley

- ☆ Pune fig is derived from *Ficus carica* × *Ficus glomerata*
- ☆ For effective fruit set in Smyrna fig: Interplanting of Capri fig is necessary
- ☆ Pruning time: December
- ☆ Training system: Single stem system (Open vase system)
- ☆ Notching is in fir for production of laterals on vigorous upright branches
- ☆ Production of parthenocarpic fruits: NAA or IBA@25ppm
- ☆ Climacteric fruit
- ☆ Capri fig produces 3 crops/year,
- ☆ Harvesting stage: Opening of ostiole and disappearance of milky latex
- ☆ Preventing dried fruits from insect attack: dipping dried fruits in boiling water or NaCl or sodium bicarbonate and then retried at 54-65°C
- ☆ Rust is a common and important diseases of fig

Physiological disorders:

- ☆ Sunburn (Due to excess pruning) is a serious problem affecting young trees
- ☆ Fruit splitting or cracking: is due to sudden change in atmospheric humidity and soil moisture level
- ☆ Fruit drop is due to excess heat and drought, cold nights, light frost and lack of pollination

7. BAEL

7. **Bael /Symbol of Lord Shiva fruit**: *Aegle marmelos:* Myrtaceae 2n=2X=18: Origin: India
   - ☆ Deciduous tree
   - ☆ Sacred as the trifoliate leaves are offered to the Lord Shiva while fruits form holy offering during 'havan'.
   - ☆ Fruit pulp used for sherbet and marmalade
   - ☆ Ripe fruit is laxative and good for heart and brain
   - ☆ Susceptible to waterlogging
   - ☆ Highly tolerant to sodicity, salinity and stoned soils

☆ Dimorphic twigs is special feature of bael
☆ "Marmelosin" is present all parts of the plants
☆ Fruit: Hard shelled berry (Amphisarica)
☆ Edible portion: Succulent placenta
☆ Most widely used fruit crop for preserve making: Mature green fruits is ideal
☆ **Popular types:** Mirzapuri, Kagzi Gonda, Kagzi Etawah, Kagzi Banarasi, Narendra Bael-1, Narendra Bael-2
☆ **Varieties:** Pant Aparna (thornless type), Pant Shivani, Pant Urvashi, Pant Sujata, Goma Yash
☆ Thar Divya: suitable for rainfed dryland regions
☆ Commercially propagation: Patch budding (June to July is ideal time)
☆ Spacing: 8m×8m for budded plants and 10m×10m for seedlings
☆ Flowering time: May-June
☆ Harvesting time: April-May
☆ Climacteric fruit
☆ Among the fruits, bael takes longest duration for fruit set to ripening (11 months)
☆ Bael fruits remain intact on the tree for longest time

8. PHALSA

8. **Phalsa/Dhamani:** *Grewia subinequalis* (Syn. *G. asiatica*): Tiliaceae: Origin: India
☆ Subtropical bushy fruit plant
☆ Hardy drought tolerant
☆ Woody perennial, arid zone fruit crop
☆ Well suited to close planting
☆ Suitable for intercropping in mango orchards
☆ Fruits are born in current season's growth
☆ Tolerate temperature above 45°C
☆ Leaf extract of phalsa has antibacterial activity against *Escherichia coli* and *Staphylococcus aureus*
☆ Commercially propagation: Seeds
☆ **Two types:** Tall and Dwarf (Commonly grown and more productive)
☆ **Variety:** Sharbati
☆ Spacing: 2m × 2m (250 plants/ha)
☆ Phalsa needs heavy pruning
☆ Pruning time: December to January
☆ Iron chlorosis of phalsa is main problem in calcareous soil

9. JAMUN

9. **Java Plum/Jamun/Indian Black Berry:** *Syzygium cuminii* (Syn. *Eugenia jambolana*): Myrtaceae: Origin: India
- Used as avenue tree or as wind break tree
- Hardy evergreen fruit tree
- Fruits are a good sources of iron
- Jamun seeds effective medicine for diabetes.
- Used as an effective medicine against diabetes, heart and liver trouble
- Chromosome number: 2n=2X=44, 66
- Hexaploid tree
- Main responsible for astringency: tannin
- Purple colour of fruit is due to anthocyanin pigments
- Responsible for flavour of fruits: Dihydrocarvyl acetate, geranyl butyrate and terpenyl valerate
- Seed powder: reduce the quantity of sugar in the urine very quickly
- Seeds contain an alkaloid Jambosin and a glycoside Jambolin or Antimellin which reduce the diastatic conversion of starch to sugars
- Type of pollination: Highly cross pollinated through honey bees, houseflies and wind

Related species:

Common name	Botanical name
Rose apple	*Syzygium jambose*
Watery Rose Apple	*Syzygium aqueum*
Malay Rose Apple/Malayan Apple	*Syzygium malaccense*
Surinam Cherry	*Syzygium uniflora*

Varieties:
- Ra Jamun (Paras) - Large sized fruits
- Seedless type: CISH J-42
- Goma Priyanka: Early type, semi dwarf
- Dhoopdal: popular in Karnataka (Registered for Geographic indications (GI) tag

☆ Propagation: Seed (Recalcitrant)
☆ Successful for commercial raising of plants: Budding method
☆ Do not require pruning
☆ Flowering time: March to April
☆ Inflorescence: Panicle
☆ Fruits ripe during June-July
☆ Non-climacteric fruit

10. KARONDA

10. **Karonda/Java plum/Christ thorn**: *Carissa carandas*: Apocynaceae: 2n=2X=22: Origin: Ind

- ☆ Evergreen, spiny shrub
- ☆ Fruits are very useful for cure anaemia and antiscorbutic properties
- ☆ Fruits rich source of iron
- ☆ Hardy and drought tolerant
- ☆ African species: Natal plum (*Carissa grandiflora*)
- ☆ Commonly propagation: Seeds
- ☆ Training system: Single or double system
- ☆ Flowering time: March
- ☆ Ripening or harvesting time: July to September
- ☆ Fruits mature 100-110 days after fruit set

11. WEST INDIAN CHERRY

11. **Puerto Rican Cherry/Barbados or West Indian Cherry**: *Malphigia punicifolia*: Malphigiaceae
Origin: South America

- ☆ Tropical evergreen shrub
- ☆ Ideal fruit plant for kitchen garden
- ☆ Richest source of vitamin-C (1400 mg/100g) than the Aonla (600 mg/100g) so called "Vitamin C tablet fruit"
- ☆ Suitable filler crop for mango, sapota and guava
- ☆ Propagation: Ground layering
- ☆ Spacing: 2m×2m

12. CARAMBOLA

12. **Star fruit or carambola**: *Averrhoa carambola*: Oxalidaceae 2n=2X=24: Origin: Indonesia

- ☆ Prefers warm moist climate
- ☆ Humid tropical tree
- ☆ Cauliflorous bearing habit
- ☆ Root extract is used as an antidote for poisoning
- ☆ Crushed leaves is used for curing chicken pox, ringworm and scabies
- ☆ Acidity in fruit is due to oxalic acid
- ☆ Rich source of oxalic acid
- ☆ Recalcitrant seeds

- ☆ Fruit cum ornamental tree in gardening

Related species:

- ✦ Cucumber tree (*Averrhoa bilimbi*): Produces gherkin like fruits: Used for pickles
- ✦ Substitute for tamarind

2 types:

a. Sour types- 1% acid
b. Sweet types- low acid 0.4%with 5% sugars eg. Fuang Tung (Chinese sweet type)

Varieties:

- ✦ Golden Star (Hawaii)
- ✦ Icambola (Columbia)
- ✦ Tean Ma and Min Tao (Taiwan)
- ✦ Dah Pon

- ☆ Spacing: 8m × 8m
- ☆ Bearing time: July to September
- ☆ Major problem: Heterostyly flower structure

H. IMPORTANT FRUIT SCIENTIST

Mango:

- ★ Mango taxonomic classification given by Kostermans, A.J.G.H., Bompard, J.M., 1993
- ★ Mango hybridization work was started by Burns and Prayaga (1921) at Pune, Maharashtra, India
- ★ Mango caging technique suggested by Mukherjee *et al.*, (1961)
- ★ Self-incompatibility in mango was 1st reported by Singh *et al.*, (1962)
- ★ Mango hybridisation work first at I.A.R.I., New Delhi, hybridization project was initiated in 1961
- ★ Bottom heat-a new technique for rooting hardwood cuttings of tropical fruits. Reddy, Y.N. and Majumdar, P.K. (1975)

Banana:

- ★ Banana scoring techniques developed by Simmonds and Shepherd (1955)
- ★ The nomenclature system used to classify banana cultivars was developed by Norman Simmonds and Kenneth Shepherd in 1955.The system is based on 15 characters

Citrus:

- ★ Modern system of citrus classification: Swingle and Tanaka system
- ★ Walter T. Swingle (1943) (USDA USA) 16 species, 2 sub genera and 8 botanical varieties
- ★ Tanaka (1954) 2 sub genera, 144 species
- ★ Storey (1938) and Hofmeyr (1938) proposed that sex type determination in papaya is controlled by a single gene with three alleles: *M, hh,* and *m*
- ★ Kinnow: mandarin hybrid (King × Willow leaf) developed at the University of California Research Centre, Riverside by H. B. Frost in 1915 and released in 1935

Guava:

- ★ Lucknow-49 famous guava variety in India was developed by G.S Cheema and Deshmukh, Ganesh Khind Fruit Research Station (GKFRS), Pune, Maharashtra

Avocado:

- ★ Avocado botanical varieties concept given by Bergh & Ellstrand, 1986
- ★ The Dichogamous condition of avocado was 1st noticed by Nirody, (1922)

Apple:

- ★ Apple Scab resistant varieties developed by L.Fredric Hough

Grapes

- ▪ Abdul Baquer Khan introduced Anab-e-Shahi from Middle east to India in 1890

Pomegranate

- ★ Pomegranate research in India dates back to 1932. At the Ganesh Khind Fruit Experiment station, Dr. G.S. Cheema
- ★ In the year 1936 a selection from the seedling population of Alandi, bearing sweet aril type fruit with soft seeds was identified and released for commercial cultivation in Maharashtra in the name of cv.GBG-1. In the year 1970 the cultivar GBG-1 was renamed as Ganesh.

I. Major Diseases of Fruit Crops

Fruit crops	Diseases	Scientific name	Causal organisms	Remarks
Mango	Powdery mildew	*Oidium mangiferae*	Fungus	30-90% loss
	Anthracnose	*Colletotrichum gloesporoides*	Fungus	-
	Rust	*Cephaleoras mycoides*	Algal	-
	Canker	*Xanthomonas campestris pv. mangiferae*	Bacteria	-
	Sooty mould	*Capnoidum sp.*	Fungi	-
Banana	Panama wilt	*Fusarium oxysporum pv. cubense*	Soil borne fungus (Acidic)	Resistant var. Poovan
	Sigatoka leaf spot	*Cercospora musicola*	Fungus	ABB clones: Resistant
	Moko wilt	*Pseudomonas solanacearum*	Bacteria	-
	Cigar end rot	*Verticillium therobromae*		-
	Stem end rot	*Botryodiplodia theobromae*	Fungus	Blackening of fingers (Foul smell)
	Bunchy top	*Banana bunchy top virus (BBTV)*	Virus	Resistant var. Virupakshi
	Streak virus	*Banana streak virus (BSV)*	Vector: Mealy bug	-
	Bract disease	*Banana bract mosaic virus (BBMV)*	Vector: Aphids	Suceptible var. Nendran
	Kokkan disease	*Banana bract mosaic virus (BBMV)*		1st reported in Thrissur District of Kerala, India
Citrus	Die-back	*Botryodiplodia theobromae, Colletotrichum gloeosporiodides*	Fungus	-
	Gummosis	*Phytophthora spp.*	Fungus	-
	Canker	*X. campestris pv. citri* (Bacteria)	Vector: Leaf miner	Resistant var. Tenali

	Greening	*MLO's*	Vector: Psylla	-
	Tristeza	*Tristeza virus*	Virus	Indicator plant: Acid lime
	Exocortis	*Viroids*		Indicator plant: Rangpur lime and citron
	Xyloporosis		Bud wood transmission	-
Grape	Downy mildew	*Plasmopora viticola*	Fungus	-
	Powdery mildew	*Uncinula necator*	Fungus	-
	Pierce's disease	*Xyllela fastidiosa*	Fungus	-
	Anthracnose/bird eye spot	*Gloeosporium ampelophagum*		Resistant rootstock: Temple
Papaya	Damping off	*Pythium aphanidermatum*	Fungus	-
	Ring spot	*Papaya ring spot virus (PRSV)*	Vector: Aphids	-
	Leaf curl	*Papaya leaf curl virus (PLCV)*	Vector: White fly	-
	Powdery mildew	*Oidium caricae*	Fungus	-
Guava	Wilt	*Fusarium oxysporum* pv. *psidii*	Fungus	Resistant var. Allahabad Safed
	Canker	*Pestalotiopsis psidii*	Fungus	Resistant var. Apple Colour
Sapota	Leaf spot	*Phleopheospora indica*	Fungus	-
Pomegranate	Leaf spot	*Cercospora punicae*	Fungus	-
Pineapple	Wilt	*Pineapple wilt virus*	Vector: Mealy bug	-
Fig	Rust	*Cerotolium fici*	Fungus	-
Ber	Powdery mildew	*Oidium zizyphi* var. *indicae*	Fungus	-
	Black spot	*Isariopsis zizyphi*	Fungus	-
Aonla	Ring rust	*Ravenelia emblica*	Fungus	-

Apple	Apple scab	*Venturia subinaequalis*	Fungus	Crop loss: 70-80%
	Fire blight	*Erwinia amylovora*	Bacteria	-
	Leaf blotch	*Marssonina coronaria*	Fungus	Pre mature defoliation
	Powdery mildew	*Podosphareia leucotricha*		
	Crown gall	*Agrobacterium tumefaciens*	Bacteria	-
Pear	Pe r decline	*MLO's*	Vector: Psylla	-
Peach	Peach leaf curl	*Taphrina deformens*	Fungus	-
	Gummosis	*Pseudomonas spp.*	Bacteria	-
	Wisker's rot	*Rhizopus stolonifer*	Bacteria	-

Major Post Harvest Diseases of Fresh Fruits

Crops	Disease	Pathogens
Mango, Papaya	Anthracnose	*Colletotrichum gloeosporioides*
Banana	Crown rot	*Fusarium roseum, Verticillium theorbromae, Ceratocystis paradoxa*
	Anthracnose	*Colletotrichum musae*
Citrus	Stem end rot	*Phomopsis citri, Diplodia natalensis, Alternaria citri*
	Green mould rot	*Penicillium digitatum*
	Blue mould rot	*Penicillium italicum*
	Sour rot	*Geotrichum candidum*
Grape, apple, pear, strawberry	Grey mould rot	*Botrytis cinerea*
Peach, cherry	Brown rot	*Monilinia fructicola*
Peach, cherry, strawberry	Rhizopus rot	*Rhizopus stolonifer*
Pineapple	Black rot	*Ceratocystis paradoxa*

Ca Disorders in Fruits

Fruits	Symptoms
Mango	Soft nose
Apple	Bitter pit, lenticel blotch, cork spot, internal break down, senescent break down, Jonathan spot, water core, cracking
Pear	Cork spot
Avocado	End spot
Cherry	Cracking
Strawberry	Leaf tip burn

Chapter-4 : Olericulture

A. Introduction to Olericulture

★ Study of vegetable cultivation: Olericulture
★ India grows the largest number of vegetable crops in the world
★ Almost all vegetables belong to sub-community spermatophyte and division angiosperms
★ Most of the vegetables if properly grown can give yield which is 5-10 times than any cereal crop
★ Vegetables are known to the cheapest source of natural "protective food"
★ ICMR recommendation for Balance Diet:
  - Recommended dietary allowance (RDA): 300 g of Vegetables/Day, 125 g Green Leafy vegetable, 100 g Root and Tuber Crops, 75g Other Vegetables
★ Per capital availability of vegetables in India: 250 g
★ Post harvest losses of vegetable in india: 25%
★ Vegetable processing and export of india: 10%
★ World vegetable area: 59.16 Million ha, Production: 1159 Million tonnes, Productivity: 19.6 t/ha.
★ Netherlands is the largest exporter of vegetables in the world
★ India ranks 24th in the export value
★ Leading vegetable producing countries in the world
  - China (49.5%)
  - India (14 %)
  - USA (3.1%)
★ Among vegetable crops, first commercial F_1 hybrid released in world: crop: Brinjal, 1924, Japan
★ **Traditional Vegetables:** Onion, Potato, Okra, Bitter Gourd, Chilli
★ **Non-traditional Vegetables:** Celery, Asparagus, Sweet Pepper, Sweet Corn, Baby Corn, Green Peas, French Bean, Cherry Tomato

Vegetable gardening:

★ 5 cents (200 m^2) land supply adequate vegetable for 5 members family
★ Sandy loam is the best suited type of soil for vegetable crops
★ Generally 4 methods of classification of vegetables are followed
★ Most convenient method of classification of vegetables is based on culture
★ Home garden or Kitchen garden is most ancient type of garden
★ Market gardening is supply vegetables for local market
★ Truck gardening is supply vegetables for distant market
★ Market gardening is the intensive method of vegetable cultivation
★ Truck gardening is an extensive method of vegetable cultivation

★ Floating Garden is located at Dal Lake, Jammu Kashmir
★ Vegetable Forcing: Growing of vegetables in offseason e.g. Capsicum and Tomato
★ Vegetable Forcing is commercially followed in England and Other European Countries

Vegetable Research in India:

★ Temperate vegetable production started at Quetta (Pakistan): 1940
★ Plant introduction scheme sanctioned in IARI, New Delhi: 1947
★ 1st Vegetable Breeding Station (VBS) started at Katrain, Kullu Valley, Himachal Pradesh: 1949
★ Division of Horticulture started in IARI, New Delhi: 1956
★ Indian Institute of Horticultural Research (IIHR), Hessaraghatta, Bengaluru: strong focus on improvement of vegetable crops: 1968
★ All India Coordinated Vegetable Improvement Project (AICVIP) was started during the 4th five year plan in 1970-71
★ 1st Project Coordinator for AICVIP: Dr. Vishnu Swarup
★ Project Directorate of Vegetable Research was started in IARI, New Delhi:1986
★ 1st Project Director for PDVR: Dr. Kalloo (1991)
★ Head quarter of PDVR was shifted from IARI to Varanasi:1992
★ Project Directorate of Vegetable Research (PDVR) was upgraded as Indian Institute of Vegetable Research (IIVR) in 1999
★ Head quarter of AICVIP is located at IIVR, Varanasi, Uttar Pradesh
★ HQ of AICRP on tuber crops is located at Trivandrum, Kerala
★ Central Potato Research Institute was started at Shimla, Himachal Pradesh: 1948
★ Research in improvement of vegetable crops was initiated in 1947-48 at IARI, New Delhi

Heterosis breeding in vegetable crops:

★ F_1 hybrid popularity: Cucumber (1935), Tomato (1940)
★ Earliest hybrid research in the world: Hayes and Jones, 1916.
★ 1st mention of hybrid seeds in seed catalogue: 1945, USA.
★ Exploitation of hybrid vigour written in Technical bulletin, Singh and Swarup, 1962.
★ First F_1 hybrid was released in 1973: Tomato (Karnataka) and capsicum (Bharat) by Indo American Hybrid Seed Company, Bengaluru, Karnataka
★ Global vegetable seed market was shared by following group of vegetables: solanaceous (30%), cucurbits (21%), roots and bulbs (16%), brassicas (13%), large seed (13%), leafy and other (7%)
★ First F_1 hybrid in public sector: Bottlegourd (Pusa Meghdoot, Pusa Manjari) released by IARI, New Delhi
★ At the national level 1st report of hybrid vigour in chilli, 1933, IARI, New Delhi
★ ICAR initiated a network project entitled Project of Hybrid Research in Vegetable Crops during 1995-96

B. Classification of Vegetable Crops

Major classification:

1. Botanical classification
2. Classification based on the plant parts used as vegetable
3. Edible portion of vegetable crops
4. Classification based on photoperiodism
5. Type of inflorescence in vegetable crops
6. Tendrils types in cucurbit vegetables
7. Classification based on tolerance to soil acidity
8. Classification based on tolerance to soil salinity
9. Classification based on root depth
10. Classification based on water requirement
11. Classification based on respiratory activity of the produce:
12. Classification based on climacteric pattern
13. Classification of vegetable crops based on storage life
14. Based on existing storability of seeds

Miscellaneous:

1. Useful compounds present in vegetables
2. Toxic substances present in vegetable crops
3. Edible colour rich varieties in India
4. Pollination mechanism in vegetable crops
5. Inbreeding depression in vegetable crops
6. Male sterility systems in vegetable crops
   - Genetic Male Sterility (GMS) or Nuclear Male Sterility (NMS)
   - Cytoplasmic genetic male sterility (CGMS) in vegetable crops
   - Genetic-cytoplasmic male sterility (GCMS) in vegetable crops
7. Method for estimation of combining ability in vegetable crops
8. Morphological markers (for male sterility identification) in vegetable crops
9. Commonly utilized Genetic Mechanism for Hybrid Development in Vegetable Crops
10. Commonly utilized Genetic Mechanism for Hybrid Development in Cucurbit Vegetables
11. Genome sequencing in vegetable crops
12. Derivation of vegetable for plant tissue
13. Compounds responsible for vegetables
14. Major acid present in vegetable crops
15. Effects of ethylene on crops
16. Nutritive value of vegetables

1. Botanical classification:

Family	Crops	Scientific name	Edible part	Chromosome No. (2n)
Monocotyledoneae				
Alliaceae	Onion	*Allium cepa*	Bulb	
	Multiplier onion	*A. cepa var. aggregatum*	Small bulbs	16
	Top onion	*A. cepa var. viviparum*	Roots and bulbils	16
	Garlic	*A. sativum*	Cloves	16
	Leek	*A. porrum*	Blanched stem and leaves	16
	Welsh onion	*A. fistulosum*	Enlarged stem and leaves	32 (4X)
	Shallot	*A. ascalonicum*	Young bulb and green leaves	16
	Chive	*A.schoenoprasum*	Enlarged stem and leaves	16
	Kurrat	*A. kurrat*	Green leaves	16, 24, 32
Araceae	Taro	*Colocasia esculenta*	Corm and cormel	32 (4X)
	Eddoe type	*C. esculenta var. antiquorum*	Corm and cormel	24 (2X), 42 (3X)
	Dasheen type	*C. esculenta var. globulifera*	Corm and cormel	42 (3X)
	Giant taro	*Alocasia macrorrhiza*	Corm	26, 28
	Swamp taro	*Cyrtosperma chamisonis*	Corm	26, 28
	Tannia	*Xanthosoma sagittifolium*		26
	Elephant foot yam	*Amorphophallus campanulatus*	Corm	26, 28
Dioscoreaceae	Greater yam	*D. alata*	Underground stem tuber	40
	Lesser yam	*D. esculenta*	Underground stem tuber	40
	White yam	*D. rotundata*	Underground stem tuber	40
Poaceae	Sweet corn	*Zea mays var. rugosa*	Soft immature kernel	20
Asparagaceae	Asparagus	*Asparagus officinalis*	Spears	20
DICOTYLEDONEAE				
Aizoaceae	New Zealand Spinach	*Tetragonia tetragonioides*	Tender leaves and tops	32
Amaranthaceae		*Amaranthus spp.*	Leaves and stems	32
Basellaceae	Malabar spinach	*Basella rubra var. alba*	Fleshy stem and leaves	24
Apiaceae	Carrot	*Daucus carota*	Enlarged and fleshy taproot	18
	Celery	*Apium graveolens*	Leaf stalk and leaf	22
	Celeriac	*Apium graveolens var. rapaceum*	Thick, tuberous root	22
	Leaf celery	*A. graveolens var. secalinum*	Leaves	22
	Parsley	*Petroselinum crispum*	Leaves	22
	Turnip rooted parsley	*P.crispum var. tuberosum*	Swollen roots	22
	Parsnip	*Pastinaca sativa*	Large and fleshy taproot	22
	Turnip rooted chervil	*Chaerophyllum bulbosum*	Short swollen roots	
	Skirret	*Sium sisarum*	Bunch of roots that is produced from crown leaves	22
	Coriander	*Coriandrum sativum*	Young leaves	22
Chenopodiaceae	Beet root	*Beta vulgaris*	Fleshy tap root	18
	Palak	*Beta vulgaris var. bengalensis*	Leaves	18
	Chards	*Beta vulgaris var. cicla*	Large leaves and fleshy leafstalk	18

	Spinach	*Spinacia oleracea*	Rosette leaves	
	French spinach	*Atriplex hortensis*	Leaves and immature shoots	12
	Pigweed	*Chenopodium album*	Leaves and tender twigs	12
Asteraceae	Lettuce	*Lactuca sativa*	Leaves	
	Chicory	*Cichorium intybus*	Leaves	18
	Endive	*Cichorium endivia*	Leaves	18
	Globe artichoke	*Cynara scolymus*	Flower heads	18
	Jerusalem artichoke	*Helianthus tuberosus*	Root tuber	34
Convolvulaceae	Sweet potato	*Ipomea batatus*	Root tuber	102 (6X)
	Water spinach	*Ipomea aquatica*	Young terminal shoots and leaves	90 (6X)
Brassicaceae	Cabbage	*Brassica oleracea* var. *capitata*	Head	18
	Cauliflower	*Brassica oleracea* var. *sabuda*	Pre-floral apical meristem	18
	Brussels sprout	*B. oleracea* var. *gemmifera*	Immature heads	18
	Sprouting broccoli	*B. oleracea* var. *italica*	Fleshy flower stalk	18
	Knol-khol	*B. oleracea* var. *gongylodes*	Enlarged stem portion	18
	Kale/collard	*B. oleracea* var. *acephala*	Rosette leaves	18
	Chinese cabbage (Pak-choi)	*B. campestris* ssp. *chinensis*	Long leafy, elongated and compact head, fleshy petiole and leaf	20
	Chinese cabbage (Pe-tsai)	*B. campestris* ssp. *pekinensis*	Loose leafy heads	20

	Chinese Kale	*Brassica alboglabra*	Tender leaves and petioles	20
	Turnip	*B. campestris* ssp. *rapifera*	Swollen root	20
	Rutabaga	*Brassica napobrassica*	Enlarged and elongated tap root	38
	Radish	*Raphanus caudatus*	Fleshy swollen primary root	18
	Water cress	*Nasturtium officinale*	Tender mustard flavoured top and leaves	32
	Garden cress	*Lepidium sativum*	Leaves	16, 32
	Sea Kale	*Crambe maritima*	Blanched, tender leaves and shoots	
Cucurbitaceae	Cucumber	*Cucumis sativus*	Immature fruit	14
	Musk melon	*Cucumis melo*	Ripe fruit	24
	Gherkin	*Cucumis anguria*	Young fruits	24
	Watermelon	*Citrullus lanatus*	Ripe fruit	22
	Round melon	*C. lanatus* var. *fistulosus*	Immature fruit	22
	Pumpkin	*Cucurbita moschata*	Ripe fruit	40
	Summer squash	*Cucurbita pepo*	Immature fruit	40
	Winter squash	*Cucurbita maxima*	Ripe fruit	40
	Buffalo gourd	*Cucurbita ficifolia*	Fruit	40
	Bottle gourd	*Lagenaria siceraria*	Immature fruit	22
	Bitter gourd	*Momordica charantia*	Immature fruit	22
	Balsam apple	*Momordica balsamina*	Immature fruit	22
	Giant spine gourd	*Momordica cochinchinensis*	Immature fruit	28
	Ridge gourd	*Luffa acutangula*	Immature fruit	26
	Sponge gourd	*Luffa cylindrica*	Immature fruit	26
	Pointed gourd	*Trichosanthes dioica*	Immature fruit	22

	Snake gourd	*T. anguina*	Immature fruit	
	Wax gourd	*Benincasa hispida*	Immature fruit	22
	Ivy gourd	*Coccinia grandis*	Immature fruit	24
	Chow-chow	*Sechium edule*	Single seeded fruit	24
	Mitha Karela	*Cyclanthera pedata*	Immature fruit	28
Euphorbiaceae	Cassava	*Manihot esculenta*	Tuberous roots	32
	Chekkurmanis	*Sauropus androgynus*	Green leaves	36
Lamiaceae	Chinese potato	*Coleus parviflorus*	Adventitious tuberous roots	
Fabaceae	Garden pea	*Pisum sativum* var. *hortense*	Tender seeds	14
	French bean	*Phaseolus vulgaris*	Tender pod and seeds	22
	Lima bean	*Phaseolus lunatus*	Tender pods and seeds	22
	Lab-lab bean	*Lablab purpureus*	Tender pods and seeds	22
	Cluster bean	*Cyamopsis tetragonolobus*	Tender pods and seeds	14
	Winged bean	*Psophocarpus tetragonolobus*	Green, pods and seeds, flowers , roots	22
	Broad bean	*Vicia faba*	Green pods and seeds	12
	Cowpea	*Vigna unguiculata*	Tender pod, immature seed and mature seed	22
	Soy bean	*Glycine max*	Tender and dry seed	40
	Yam bean	*Pachyrrhizus erosus*	Root tuber	22
	Fenugreek	*Trigonella foenum-graceum*	Tender leaves	16
Malvaceae	Okra	*Abelmoschus esculentus*	Tender fruit	130
Moringaceae	Drumstick	*Moringa oleifera*	Green pod and leaves	28

Polygonaceae	Rhubarb	*Rheum rhaponticum*	Thick leaf stalk	44 (4X)
	Buck wheat	*Fagopyrum tataricum*	Tender tops	16
Portulacaceae	Ceylon spinach	*Talinum triangulare*	Leaf and tender stem	
Rutaceae	Curry leaf	*Murraya koenigii*	Leaves	18
Solanaceae	Potato	*Solanum tuberosum*	Stem tuber	48 (4X)
	Brinjal	*Solanum melongena*	Fruit	24
	Tomato	*Solanum lycopersicum*	Fruit	24
	Currant tomato	*Solanum pimpinellifolium*	Fruit	24
	Chilli	*Capsicum annuum*	Fruit	24

2. Classification based on the plant parts used as vegetable:

Flower	Agathi, male flowers of pumpkin
Flower head	Broccoli, globe artichoke
Prefloral apical meristem	Cauliflower
Modified above ground stem	Knolkhol, asparagus
Modified stem	Potato, Jerusalem artichoke, yam, elephant foot yam, taro, onion, garlic
Modified root	Radish, carrot, beetroot, turnip, sweet potato
Modified tap root	Chinese artichoke
Modified adventitious root	Chinese potato
Fruits	Brinjal, tomato, chilli, peas and beans, all cucurbits, okra
Corm	Colacasia, elephant foot yam

3. Edible portion of vegetable crops:

Edible part	Vegetables
Placenta	Cucumber, watermelon
Endocarp	Ridge gourd, sponge gourd, ash gourd
Mesocarp and pericarp	Pumpkin, musk melon

4. Classification based on photoperiodism:

i. Short day plants (SDP)	Sweet potato, clusterbean, winged bean, hyacinth bean, Indian spinach
ii. Long day plants (LDP)	Potato, onion, lettuce, cabbage, cauliflower, knolkhol, radish, carrot, turnip, beetroot
iii. Day neutral plants (DNP)	Tomato, brinjal, chilli, cowpea, okra, french bean, cucurbits

5. Type of inflorescence in vegetable crops:

Type of inflorescence	Crops
Raceme	Cole crops, cucurbits, radish
Cyme	Tomato brinjal, chilli, potato, spinach, sweet potato, broccoli
Panicle	Moringa, palak
Spike	Beet root
Compound Umbel	Carrot, coriander
Capitulum	Lettuce

6. Tendrils types in cucurbit vegetables:

Simple tendrils	Branched tendrils
Cucumber, ash gourd, bitter gourd, muskmelon, long melon, snap melon	Water melon , round melon Bottle gourd, snake gourd, ridge gourd, sponge gourd

7. Classification based on tolerance to soil acidity:

i. Less tolerant	Okra, onion, cabbage, cauliflower, broccoli, Chinese cabbage, musk melon
ii. Moderately tolerant	Brinjal, tomato, chilli, radish, carrot, summer squash, winter squash
iii. Very tolerant	Potato, sweet potato, rhubarb

8. Classification based on tolerance to soil salinity:

i. Less tolerant	Brinjal, sweet pepper, potato, sweet potato, pea, radish, snakegourd, beans
ii. Moderately tolerant	Tomato, chilli, watermelon, cucumber, summer squash, bottlegourd, cabbage, cauliflower, broccoli, muskmelon, onion
iii. Highly tolerant	Kale, turnip, bittergourd, ashgourd, palak, lettuce, asparagus

9. Classification based on root depth

i.	Very shallow rooted (15-30 cm)	Onion, lettuce, radish
ii.	Shallow rooted (30-60 cm)	Cole crops, potato, radish, garlic, cowpea
iii.	Moderately deep rooted (60-90 cm)	Cucumber, muskmelon, brinjal, french bean, carrot, beetroot
iv.	Deep rooted (90-120 cm)	Summer squash, chilli, pea, turnip
v.	Very deep rooted (120-180 cm)	Winter squash, pumpkin, sweet potato, tomato

10. Classification based on water requirement:

i.	High	Sweet pepper, cole crops, radish, ridge gourd, turnip, beetroot
ii.	Moderate	Tomato, brinjal, chilli, cucumber, onion, carrot, potato
iii.	Low	Peas and beans
iv.	Very low	Watermelon, muskmelon, pumpkin, ashgourd

11. Classification based on respiratory activity of the produce:

Levels	Rate of respiration (mg of CO_2/kg/hr)	Vegetable crops
Very low	5	Potato, onion
Low	5-10	Sweet potato, turnip, cucumber, cabbage
Moderate	10-20	Tomato, chilli, sweet pepper, carrot, beet
High	20-40	Radish, Indian bean, french bean, peas, lettuce, lima bean
Very high	40-60	Green onion, muskmelon, watermelon, cauliflower, broccoli, okra, brussels sprout
Extremely high	>60	Spinach, asparagus, green peas, mushroom

12. Classification based on climacteric pattern:

Climacteric vegetable	No climacteric vegetable
Tomato, Brinjal, Muskmelon	Pumpkin, cucumber, pointed gourd, chilli, capsicum, tamarillo, watermelon

13. Classification of vegetable crops based on storage life:

Very perishable (0-4 weeks)	Perishable (4-8 weeks)	Semi-perishable (6-12 weeks)	Perishable (>12 weeks)
Asparagus, beans, broccoli, brussels sprout, cauliflower, cucumber, lettuce, pea, rhubarb, spinach, sweet corn, tomato, mushroom	Cabbage	Celery, leek, marrow	Beetroot, carrot, onion, parsnip, pumpkin, potato, sweet potato, swede, turnip

14. Based on existing storability of seeds:

Group	Storability period (years)	Vegetables
Poor storer	1-2	Onion
Intermediate	2-3	Chilli, carrot, okra, French bean
Good storer-1	3-4	Cucurbits, radish, garden pea, beet root
Good storer-2	4-5	Tomato, brinjal, cole crops

Miscellaneous:

1. Useful compounds present in vegetables:

Vegetables	Compounds	Role in disease prevention
Onion, garlic	Sulphur compounds	Reducing blood cholesterol
Cole crops	Indoles and dithiolthiones	Prevention of cancer
Bittergourd	Cheratin	Effective against diabetes
Onion	Diphenyl amine	Effective against diabetes
Celery	3-n-butyl pthalide	Effective against hypertension
Yams	Diosgenin	Manufacture of contraceptive drugs
Onion, garlic	Quercetin (Bioflavonoids)	Protection against cancer & heart diseases
Lettuce	Lutein	Nutritional antioxidant
Onion	Allicin	Antibacterial activity
Cabbage	Indole-3-carbinol	Against bowl cancer
Broccoli	Sulphoraphane	Anticancer activity
French bean, broccoli	Kaemferol	Anti cancer and cardiovascular disease
Brinjal	Nasunin (Anthocyanin)	Anticancer activity
Broccoli	Glucoraphinanin	Anticancer activity

2. Toxic substances present in vegetable crops:

Toxic substances	Crops
Trypsin inhibitors	Soybean
Cyanogenic glycosides	Lima bean
Protease inhibitors	Lima bean, faba bean
Ipomeamarone	Sweet potato
Phytic acid	Peas and Beans (Mature seeds)
Oxalic acid	Amaranth, Portulaca, Celosia, Basella, Colocasia
Oxalates	Rhubarb, Beets, chard, spinach, New Zealand spinach
Calcium oxalate	Elephant foot yam, Colocasia
Hydrocyanic acid	Tapioca (more in leaves)
Dioscorine	Yams
Solanine	Potato
Solasodine	Brinjal
Serotonin	Watermelon
Cholinesterase inhibitors	Pumpkin and squash
Sinigrin	Cole crops
Saponine	Spinach, Asparagus, Tomato
Cucurbitacins	Cucurbits
Apiin	Celery

Homagglutinins	Common beans
Vicine and covicine	Broad bean
Tomatine	Tomato
Lactucopicrin	lettuce

3. Edible colour rich varieties in India:

Crop	Variety	Pigments
Carrot	Pusa Asita	Anthocyanins
	Pusa Rudhira	Lycopene
	Pusa Nayanjyothi	β-carotene
Radish	Palam Hriday	Anthocyanin
Broccoli	Palam Vichitra	Anthocyanin
Amaranth	Pusa Lal Chaulai	Anthocyanin
Tomato	Pusa Rohini	Lycopene
Beetroot	Detroit Dark Red	Anthocyanin
Paprika	KTPL-19	Capsanthin
Pumpkin	Arka Chandan	β-carotene

4. Pollination mechanism in vegetable crops

Types	Extent of cross pollination	Crops
Self pollinated crops	0-5%	Tomato, Garden Pea, Beans, Lettuce
Often-Cross pollinated crops	5-12%	Chilli, Capsicum, Brinjal, Okra
Cross pollinated	>12%	Cole crops, Cucurbits

★ The genetic structure of autogamous vegetable crops are homozygous

★ Genotypically allogamous vegetable crops are heterozygous

Self pollinated crops (Autogamous):

★ **Mechanism which promotes for autogamy:**

- Homomorphism
- Cleistogamy eg. Lettuce, peas and beans
- Chasmogamy eg. Tomato

Cross pollinated crops (Allogamous):

★ **Mechanism which promotes for allogamy:**

- Separation of sex: *e.g.* cucurbits
- Hetermorphism
- Heterostyly eg. Brinjal
- Dichogamy: Protandry e.g. Carrot, onion, beet, parsley, leek
  Protogyny e.g. Okra, chilli, elephant foot yam, cole crops
- Self incompatibility:
  - ✦ Gametophytic SI e.g. Tomato
  - ✦ Sporophytic SI e.g. Cole crops, sweet potato

Dichogamy mechanism in vegetable crops:

Protandry	Protogyny
Onion, carrot, muskmelon, pointed gourd	Chilli, cole crops, okra, cassava, amaranthus, taro
Rhubarb, parsnip, leek, garden beet, swisschard	Elephant foot yam

5. Inbreeding depression in vegetable crops:

★ Inbreeding depression is the loss of vigour due to inbreeding/selfing

★ Inbreeding depression = F_1-F_2/F_1/100

Level of inbreeding depression	Crops	Extent of inbreeding
Very high	Carrot	2 years
High	Onion	2-3 years
Moderate high	Cabbage, cauliflower (maturity Group I and II), broccoli, brussels sprouts, turnip, sweet corn, radish	3-4 years
Low	Snowball group of cauliflower (Maturity group IV)	4-5 years
No inbreeding depression	All cucurbits ,tomato, peas, beans, brinjal, lettuce	-

6. Male sterility systems in vegetable crops:

Types of male sterility	Inheritance pattern	Vegetable crops
1. Pollen sterility		
a. Cytoplasmic male sterility (CMS)	Not occur in nature	-
b. Genic male sterility (GMS)	Singe recessive gene (*ms*)	Tomato, brinjal, garden pea, muskmelon, watermelon, chilli, lima bean, pumpkin, cucumber, cole crops
	Duplicate dominant gene	Cauliflower
c. Cytoplasmic-Genic male sterility (CGMS)	Single recessive gene (*ms*)	Onion, radish, sweet pepper, cole crops, turnip
	Two recessive gene	Beet
	Single dominant gene	Carrot
2. Staminal male sterility (*sl*)	Single recessive gene	Tomato
3. Structural/Functional male sterility		
i. Positional sterility (*ps*)	Single recessive gene	Tomato, brinjal, sweet pepper
ii. Exserted stigma sterility (*ex*)	Single recessive gene	Tomato

A. Genetic Male Sterility (GMS) or Nuclear Male Sterility (NMS):

Crops	Inheritance	Commercially utilized genes	Hybrids
Tomato	Single recessive gene	*ps-2*	-
Chilli	Single recessive gene	*ms-12 & ms-3*	CH-1,CH-3
Muskmelon	Single recessive gene	*ms-1*	Punjab Hybrid-1

B. Cytoplasmic genetic male sterility (CGMS) in vegetable crops:

Crops	Gene	Commercially utilised	Varieties
Chilli	Single recessive gene	*ms-2*	Arka Meghana, Arka Sweta, Arka Harita, Kashi Surkh
Onion	Single recessive gene	*S* cytoplasm	Arka Kirtiman, Arka Lalima
	Single recessive gene	*pt*	Pusa Nayanjyothi, Pusa Vasuda

C. Genetic-cytoplasmic male sterility (GCMS) in vegetable crops:

Crops	Types	Commercially utilised
Onion	S and T cytoplasm	S-cytoplasm type
Carrot	Petaloid (*pt*), brown anther (*ba*) and gummifer (*gu*)	Petaloid type
Cauliflower	-	Ogura cytoplasm
Cabbage	-	Ogura cytoplasm
Brussels sprouts	-	Ogura cytoplasm
Sprouting Broccoli	-	Ogura cytoplasm

7. Method for estimation of combining ability in vegetable crops:

Combining ability	Mating design
GCA	Top cross, Poly Cross
SCA	Single cross, Pair Cross
GCA and SCA	Diallel cross

*General Combining Ability (GCA) and Specific Combining Ability (SCA)

8. Morphological markers (identification male sterility plants at early stage) in vegetable crops:

Morphological markers	Vegetables
Potato leaf, green stem, anthocyaninless stem	Tomato
Glabrous seedling	Muskmelon
Non-lobed leaf, glabrous leaf, delayed green seedling	Water melon
Glossy foliage	Brussels sprouts
Purple stem pigmentation	Cabbage
Brown seed coat colour	Onion
Bright green hypocotyls	Broccoli

9. Commonly utilized Genetic Mechanism for Hybrid Development in Vegetable Crops

Mechanism	Vegetables	Remarks
Hand emasculation and mechanical pollination	Tomato, brinjal, okra, capsicum	Commercial
GMS and hand pollination	Tomato, chilli	Commercial
CMS/CGMS and insect (natural) pollination	Onion, carrot, cauliflower, radish, chilli, capsicum	Commercial
Self incompatibility and insect (natural) pollination	Cole crops	Commercial
Manual control	Tomato, brinjal	-
Monoecy	Sweet corn	-
Dioecy	Spinach	-

10. Commonly utilized Genetic Mechanism for Hybrid Development in Cucurbits

Mechanism	Cucurbit vegetables	Remarks
Hand pollination without emasculation	Pumpkin All monoecious cucurbits	Commercial method
Emasculation and hand pollination	Musk melon	Due to Andromonoecious flower structure
Pinching of male flowers and allow to open pollination	Bottle gourd	Commercial scale
	Pumpkin , squash	Suitable method due to long pedicel of male flowers
Use of gynoecious lines	Cucumber, musk melon	Commercially exploited
Use of monoecious lines	Musk melon	Problem due to uneven fruit shape
Use of genetic male sterility (GMS) system	Musk melon	Commercially exploited
Use of maker genes	Water melon	Non-lobing leaf
	Pumpkin	Yellow spot on the upper surface of the leaves
Defloration	Cucumber	Old strategy

11. Completed and released genome sequences in vegetable crops:

Crops	Genome size	Mapping population used	Sequenced year
Potato	844 Mbp	RH 89-039-16 (Diploid heterozygotes) DM-1-3-516R44 (Double monoploid)	2011(1st sequenced tuber vegetable)
Chinese cabbage	283.8 Mbp	Chiifu-401-42	2011
Tomato	950 Mbp	'Heinz 1706	2012
S.pimpinellifolium	739 Mbp	LA1589	2012
Cucumber	367 Mbp	Chinese Long " 9930"	2009 (1st sequenced vegetable)
Melon	450 Mbp	Double-haploid line (DHL92)	2012
Watermelon	375 Mbp	-	2012
Common bean	520 Mbp	-	2013
Chilli	650.2 Gb	CM334	2014
Carrot	480 Mbp		2016
Radish	383 Mbp		2015

12. Derivation of vegetable for plant tissue:

- ★ Inflorescences: Broccoli, cauliflower
- ★ Stem sprout: Asparagus
- ★ Axillary bud: Brussels sprout
- ★ Petiole: Celery
- ★ Swollen leaf base: Leek
- ★ Leaf blade: Spinach
- ★ Terminal leaf buds: Cabbage
- ★ Swollen taproot: Carrot
- ★ Stem: Potato
- ★ Swollen hypocotyl: Beetroot
- ★ Modified stem: Onion
- ★ Flower bud: Artichoke
- ★ Placental intralocular tissue (septum)

13. Compounds responsible for vegetables:

Vegetables	Compounds
Cucumber- Raw	2, 6-Nonadienal
Cucumber-Cooked	Dimethyl disulphide
Mushroom	1-Octen-3-ol, lenthionine
Potato	2-Methoxy-3-ethyl pyrazine, 2,5- Dimethyl pyrazine
Radish	4-Methylthio-trans-3-butenyl isothiocyanate

14. Major acid present in vegetable crops:

Citric acid	Malic acid
Tomato, leafy vegetables, legumes, potato	Broccoli, carrot, celery, lettuce, onion

15. Effects of ethylene on crops:

Crops	Effects
Lettuce	Russet sprouting, discolouration
Carrot, beet	Bitterness
Celery	Blanching
Cabbage	Leaf abscission, undesirable flavour
Asparagus	Fibrousness
Cucumber	Degreening
Peas	Toxin pisatin formation
Sweet potato	Hard core, production of phenolics

16. Nutritive value of vegetables:

Nutrition	Rank wise (100g)
Vitamin-A	Bathua leaves (11,300 IU) > Colocasia leaves(10, 276 IU)>Beet leaves (9770 IU)
Vitamin- B1	Chilli (0.55 mg)
Vitamin-B2	Fenugreek (0.31 mg)
Vitamin-C	Drumstick leaves (220 mg) > Coriander leaves (135 mg) > Chilli (321 mg)
Carbohydrates	Tapioca (38.1%) > Sweet Potato (28.2%) > Potato (22.6%)
Protein	Lima bean (7.9 g) > Peas (7.2 g) > Cowpea (4.3 g)
Fibre	Potato (752 g) > Chilli (6.8 g)
Calcium	Agathi (1130 mg) > Curry leaves (813 mg)
Phosphorus	Amaranthus (800 mg) > Garlic (187 mg)
Iron	Amaranthus (22.9%)
Calorific value	Tapioca (338 mg) > Garlic (142 mg) > Lima bean (105 mg)
Potassium	Spinach (605 mg) > Amaranthus (230 mg)

C. Solanaceous Vegetable Crops

Solanaceous Vegetable Crops

1. Tomato
2. Brinjal
3. Chilli
4. Capsicum

Malvaceous Vegetable Crop

5. Okra

1. TOMATO

1. **Wolf Peach:** *Solanum lycopersicum*: Solanaceae: 2n=2X=24: Origin: South America
   - ★ Tomato is considered as "Poor man's Orange" in India while Love of Apple in England
   - ★ Tomato is universally treated as a Protective food
   - ★ Tomato world's largest vegetable crop cultivated after potato and sweet potato
   - ★ About 33% of total tomato growing area is covered by F_1 hybrids which is highest among the vegetables grown in India
   - ★ Most important tomato growing state: Andhra Pradesh (17.9%)
   - ★ Leading tomato producing states: Andhra Pradesh > Karnataka > MP
   - ★ Highest Productivity: Karnataka (33 t/ha)
   - ★ Leading tomato producing countries in world: China > India (11.5%) > USA
   - ★ Rich in vitamin-C: 20-25 mg/100g and potassium (200-210 mg/100 g)
   - ★ Most tomato varieties vary in soluble solids from 4.5-7%
   - ★ Tomato seeds contain 24% oil
   - ★ Tomato pigments:
     - i. Red colour → Lycopene
     - ii. Yellow colour → Carotenoids pigment (β-carotene)
     - iii. Tangerine colour → Pro-lycopene (cis-lycopene) pigment
   - ★ Lycopene is a natural carotenoids
   - ★ Fruit rich in the carotenoids lycopene and β-carotene (provitamin A): anticancer properties
   - ★ Main anticancer activity: Lycopene
   - ★ Tomato is the richest source of lycopene among all fruits and vegetables
   - ★ Most tomato varieties are red in colour due to the red carotenoid lycopene
   - ★ Tangerine colour tomatoes source of cis-lycopene
   - ★ Tomato fruit contains lycopene 30-50 µg/g of fresh fruit tissue
   - ★ Optimum temperature for pollination: 21°C

- ★ Lycopene production is highest at 21-24°C
- ★ Production of lycopene pigment drops off rapidly above 27°C
- ★ Reasons for failure to fruit set: i) day temperature >38°C ii) Night temperature < 13°C
- ★ Day temperatures exceeding 38°C affects the fruit set
- ★ The range of pH for the tomato fruit is between 4.0 and 4.5
- ★ Lower the pH, the greater quality (tartness)
- ★ The normal tomato varieties TSS ranged to 4-6%
- ★ Lycopene is being called the world's most powerful antioxidant
- ★ Cultivated tomato is divided into two types, *indeterminate (green house)* and *determinate (open field/processing tomato)*
- ★ More than 90% of the fresh weight of the tomato fruit is water
- ★ Tomatine is a steroidal glycoalkaloid present in tomato
- ★ Tomatine content is higher in leaves and flowers than fruits
- ★ Fruit aroma is due to presence of sulfonium
- ★ Tomato acidity is due to citric acid
- ★ Highly self-pollinated due to homomorphism and chasmogamy
- ★ Anther dehiscence: longitudinal slit
- ★ Type of inflorescence: Cymose which may be simple (single cyme) or compound (more than one cyme)
- ★ Tomato fruit: berry with 2 to 12 locules
- ★ Optimum CO_2 concentration in greenhouse tomato: 4000 ppm
- ★ Husk tomato: *Physalis pubescens*

Important species:

Botanical name	Specific features
Solanum lycopersicum var. *cerasiformae*	Ancestor of cultivated tomato
Solanum pimpinellifolium	Currant tomato
Solanum peruvianum	Source of tomato spotted wilt virus (*Sw5* gene), Tospovirus and RKN (*Mi*)
Solanum pennelli	Tolerance to drought, high Brix content
Solanum cheesmaniae	Resistant to salt
S. lycopersicum var. *cerasiforme* L.	Tolerance to humidity, resistance to fungi and root rot
S. cheesmaniae	*Jointless* gene (*j-2*), β-carotene and thick pericarp
S. pimpinellifolium	Colour, characteristics of quality, resistance to diseases

S. galapagense	Tolerance to salt
S. chmielewskii	High TSS (10%)
S. neorickii	Resistance to bacterial disease
S. habrochaites	Tolerance to cold and chilling, resistance to insects and diseases (TMV)
S. chilense	Resistance to drought and diseases (CMV, TYLCV)

- For indeterminate tomato single stem training is most common
- Training, Staking and pruning are followed in indeterminate type of tomato
- Self-topping/self-pruning (*sp*)- term related to determinate growth habit of tomato
- Antherless/Stamenless and closed anther mutant is a male sterility types found in tomato
- Tomato male sterility is governed by single recessive gene
- Total 55 male sterile lines reported in tomato
- Function male sterile line (*ps*-2) is commercially used for hybrid seed production in the world
- GMS line maintained by heterogenous male fertile line
- Crimson gene (*ogc*) improves lycopene but reduces carotene, reduces vitamin A by 25%
- The *hp* gene increases vitamin A content by 25-50%
- TLCV resistance genes
  - *Ty-1*, *Ty-3*, *Ty-4*, *Ty6* genes derived from *S.chilense*
  - *Ty-2* gene from *S. habrochaites*
  - *ty-5* gene from *S. peruvianum*
  - *Ty-1* and *Ty-3* pyramided genes commercially utilized in north India
  - *Ty-2* gene commercially utilized in south India
- Total nursery area for tomato: 250 m^2
- Seed rate: 400-500 g/ha
- Hybrid seed rate: 100-150 g/ha
- Tomato seed germination inhibited by caffic acid and ferulic acid
- Seed treatment of tomato with 2,4-D @ 2-5 ppm increases fruit set, earliness and parthenocarpy
- Early spring and autumn failure of fruit set in tomato is a common problem in India
- To enhance the fruit set at high temperature: Tomatotone or Tomatolour (CPA 4-Chlorophenoxy acetic acid)
- Reduce the incidence of leaf curl virus in tomato- CCC @ 250 ppm

- To enhance the ripening of tomato fruits, Ethrel @ 1000 ppm
- GA_3 induces parthenocarpy fruits
- In protected cultivation: Pollination is best accomplished with an electric pollinator
- The optimum relative humidity for greenhouse tomatoes is 60-70 %
- Tomato parthenocarpy is facultative type
- In tomato, maximum acidity is found when fruits are harvest at pink Stage
- For processing purpose pH of juice should be 4.5
- In tomato ideal variety for processing should have an acid content of 0.35% as citric acid
- Maturity indices:
  - For distant market → mature green stage
  - For local market →Breaker stage
  - Assessment of tomato fruit firmness by Durometer
- Cherry tomato is preferred for export in European countries
- Processed products of tomato puree and paste have great demand in export
- Tomato is a climacteric fruit
- Ripening mutants (*rin*, *nor*, *nr*) are non-climacteric fruit
- Tomato precooling temperature: 13°C
- The optimum storage temperature for ripe fruit: 7.2-10°C, RH 85–96%
- Mature green fruit can be stored at 12.7-15.5°C
- BIS has specified 4 grades: Super A, Super, Fancy and Commercial
- Best method of seed extraction: Alkali treatment (10% washing soda)
- Acid treatments by seed separation: using commercial grade HCl @ 100 ml per 10 kg of tomato pulp for half an hour's time. It takes only about after which the seeds are cleaned up and dried to desirable moisture content
- Average seed yield: 100-120 kg/ha
- Transgenic variety: Flavr Savr (long shelf life) is developed by Calgene company
- In India the book entitled "Tomato" was written by Dr. G. Kallo in 1986
- Tomato genome was fully sequenced in 2012
- Tomato genome size = 900 Mbp
- Father of tomato breeding: Dr. C.M. Rick, University of California, USA
- Father of tomato: Dr. Goutham Kallo
- Tomato Genetics Cooperative (TGC) is located at University of California, USA

Varieties of tomato:

Varieties	Breeding methods	Special features
Introduction from USA	Roma, Labonita, Sioux, Marvel, Best of All, Money Maker	
IARI Varieties:		
Pusa Red Plum	Tomato × *S. pimpinellifolium*	Interspecific hybrid, Rich in Vitamin-C
Pusa Ruby	Sioux × Improved Meeruti	Most famous variety of tomato
Pusa Early Dwarf	Improved Meeruti × Red Cloud	-
Pusa Rohini	Highly suitable for long distance transportation and processing	
Pusa Sheetal	-	-
Pusa Sadabahar	-	-
IIHR Varieties:		
Arka Vikas	Selection from Tip Top	Suitable for fresh market, rainfed variety
Arka Alok (BWR-5)	-	Resistant to bacterial wilt
Arka Abha (BWR-1)	-	Resistant to bacterial wilt
Arka Abhijit	-	Highly resistant to bacterial wilt
Arka Ashish	-	-
Arka Saurabh	Selection from V-685	Suitable for fresh and long transport
Arka Ahuti	-	Suitable for processing
Arka Meghali	Arka Vikas × IHR-554	Rainfed variety
IIVR, Varanasi		
Kashi Vishesh	*S. habrochaites* B'6013'	Resistant to TLCV
Kashi Amrit, Kashi Sharad, Kashi Hemant, Kashi Anupam		
Other Varieties:		
HS-101, HS-102, HS-110, Hisar Arun, Hisar Lalima		
Hisar Lalit	-	Resistance to rook knot nematode
Hisar Anmol	Hisar Arun × *S. hirsutum f. glabratum*	Resistance to tomato leaf curl virus
Punjab Chhuhara	EC-55005 × Punjab Tropic	Suitable for long transport
CO-1	Selection from "Kalyanpur"	Semi-determinate

CO-2	Introduction-"Russia"	Indeterminate
Paiyur-1	Pusa Ruby × CO-3	Rainfed variety
MPKV, Rahuri		
Phule Raja	-	-
Dhanashree	-	-
Dr.B.S.Konkan Krishi Vidyapeeth, Dapoli		
Sonali	VC 48-1 × Tamu chico III	Bacterial wilt resistant
Mutant Variety:		
CO-3 (Marutham)	Mutant of CO-1	-
S-12	X-ray mutant of Sioux	-
PKM-1	Mutant of Annanji	Green flesh type, Long distance transport
Pusa Lal Meeruti	Gamma ray mutant of Meeruti	-
F_1 hybrid:		
Arka Vishal	IHR 837 × IHR 932	Tolerant to cracking and suitable for fresh market
Arka Vardan	IHR 550-3 × IHR 932	-
Arka Shreshta	15 SBSB × IIHR 1614	Resistant to bacterial wilt
Arka Samrat	-	Resistance to TOLCV, bacterial wilt and early blight
Arka Rakshak	-	Resistance to TOLCV, bacterial wilt and early blight
Arka Ananya	-	Resistance to TOLCV and bacterial wilt
Arka Abhijit	-	Resistant to bacterial wilt
Pusa Divya	-	Developed using male sterile line, Antherless mutant
Pusa Hybrid-1	-	Fruit set at high night temperature
Pusa Hybrid-2	-	Highly tolerant to root knot nema
Pusa Hybrid-4	-	Field resistanc
Pusa Hybrid-8	-	
Other F_1 Hybrids	Rajashree, COTH-1, COTH-2, COT TH-802	

Important variety with features:

- ★ Suitable for northern plains: Pusa Ruby, Pusa Rohini, Pusa-120, Pusa Uphar
- ★ Determinate: Pusa Sheetal, Punjab Chhuhara, Roma,
- ★ Indeterminate: Pusa Ruby, Sioux, Marglobe, Best of All
- ★ Suitable for hills: Sioux, Best of All, Marglobe
- ★ High β-carotene variety: Caro-Rich
- ★ Parthenocarpic variety of tomato: Severianin
- ★ Suitable for processing varieties: Roma, S-152, Pusa Sheetal, NDT-120, 101, Pant Bahar, Melka Shola and Melka
- ★ Fusarium wilt resistant variety: Marglobe, Rutgers, Pritchard, Manalucie
- ★ Root knot nematode resistant varieties: Pusa-120, Hisar Lalit, Nematax, Anahu
- ★ Resistant to bacterial wilt: Arka Alok, Arka Abhijit, Arka Shreshtha
- ★ Triple disease resistance to TOLCV, bacterial wilt and early blight: Arka Samrat

Disease and pest of tomato:

Fungal disease

Disease	Scientific name	Symptoms
Late blight	*Phytophthora infestans*	Leaf and stem necrosis
Early blight (collar rot)	*Alternaria solani*	Dark, small and coalescing concentric lesions (target-like appearance) on lower older leaves
Fusarium wilt (vascular wilt, storage rot)	*Fusarium oxysporum f. sp. lycopersici*	Leaf chlorosis and wilting
Powdery mildew	*Oidium lycopersici*	Major problem in green house conditions

Bacterial disease

Disease	Scientific name	Symptoms
Bacterial wilt	*Pseudomonas solanacerum*	Serious disease of tomato in tropical humid climate (West Bengal, Kerala and Orissa)
Bacterial Canker (gram-positive)	*Clavibacter michiganensis* subsp. *michiganensis*	Marginal browning or necrosis (firing) bird's eye appearance
Bacterial speck	*Pseudomonas syringae* pv. tomato	-
Bacterial spot (gram-negative)	*Xanthomonas campestris* pv. *vesicatoria*	Problem in warm, humid regions dark, water soaked, greasy-appearing lesions

Viruses

Diseases	Vectors	Remarks
Tomato Mosaic Virus	Mechanical transmission	Major virus in green house conditions
Tomato mottle virus (ToMoV)	Whitefly	Bipartite geminivirus
Tomato Spotted wilt virus (TSWV)	Thrips	Tospovirus
Tomato Yellow Leaf Curl (TYLCV)	Whitefly	*Ty-2* commercially used in India. Source of *Ty-2* gene (*S. habrochaites*)
Cucumber mosaic virus (CMV)	Aphids	
Major Pests:		
Tomato fruit borer	*Helicoverba armigera*	Most common pest
White fly	*Bemisia tabaci*	Transmitting tomato leaf curl virus
Serpentine leaf miner	*Liriomyza trifoli*	Emerging problem

Physiological disorders of tomato :

Physiological disorders	Causes	Remedy
Fruit cracking	Boron deficiency, Effect of soil temperature	Borax spray (0.25%)
Blotchy ripening (Gray Wall)	K deficiency	Application K
Blossom end rot (BER)	Ca deficiency : Major problem in green house	CaCl (0.5%) spray
Puffiness or Pocket	Low/high temperature + Poor pollination	
Sun scald	Excessive exposure to high temperature	
Cat face	Symptoms: Distortion of the blossom end of the fruit (high or low temperature at fruit set)	
Golden flake	Low K: Ca ratio and Excess of calcium oxalate	
Russetting	the fruit skin appears roughened, especially along the shoulder	
Zipper Scar	This is a vertical scar along the side of the fruit that resembles a zipper	

Tomato leaf curl virus (TLCV):

- ❖ Most serious disease of tomato in India
- ❖ Source of resistance: *S. chilense*
- ❖ Most severe in autumn crop (Rainy season crop)

- 1g seeds of brinjal contains about 250 seeds
- Longer storage period the seeds should be dried to a moisture level of 6%
- Processing cultivars should have high dry matter and low level of phenolics
- *Mimosa pudica* plants should be planted in vicinity of brinjal to enhance the pollination
- Sarkanda Grass (*Erianthus arundinaceus*) used as mulching material in brinjal
- Application of 2,4-D @ 2 ppm flowering induces parthenocarpy, increase fruit-set, earliness and total yield
- Green brinjal fruits has longest shelf-life (4 weeks)
- Nagai and Kida first reported hybrid vigour in Brinjal in 1926
- Diosgenin is the most important source of raw material for the synthesis of steroid drugs
- Solasodine, which is chemically very close to diosgenin
- Commercial Solasodine yielding species: *S. auviculure, S. luciniutum* (high) and *S. khasianum*

Pest and diseases:

- Shoot and fruit borer (*Leucinodes orbonalis*) is the major pest of brinjal
- Yield loss due to shoot and fruit borer: 70%
- *Phomopsis* blight (*Phomopsis vexans*) is serious disease in seed production
- Bacterial wilt (*Pseudomonas solanacearum*) is a serious disease in West Bengal and Orissa
- *Fusarium* wilt, *Verticillium* wilt is major vascular diseases
- In 1939, Thomas and Krishnaswamy was first reported little leaf disease of brinjal in India
- Little leaf of brinjal is most serious disease causing MLO (Crop loss: 40-80%)
- Little leaf of brinjal is transmitted by leaf hoppers (Jassids)- *Amrasca devastans* and *Hishimonus phycitis*
- Transgenic brinjal in India developed by MAHYCO using *Cry 1Ac* gene against fruit and shoot borer
- *Orobanche spp.* (root parasite) is the serious weed of brinjal

Varieties of brinjal:

Varieties	Breeding methods	Special features
IARI Varieties:		
Pusa Purple Long	-	-
Pusa Purple Round	-	-
Pusa Purple Cluster	-	Resistant to little leaf and bacterial wilt
Pusa Kranti	-	-
Pusa Bhairav	-	Resistant to Phomopsis fruit rot (*Phomopsis vexans*)
Pusa Anupam (Kt-4)	-	Resistant to bacterial wilt
Pusa Uttam	-	-
Pusa Upkar	-	-
Pusa Bindu	-	-
Pusa Ankur	-	-
Pusa Shyamala	-	-
IIHR Varieties:		
Arka Shirish	Indigenous	-
Arka Sheel	Indigenous	-
Arka Kusumkar	Indigenous	Cluster bearing, green fruit colour
Arka Nidhi (BWR-12)	-	Resistant to bacterial wilt
Arka Keshav (BWR-21)	-	Resistant to bacterial wilt
IIVR, Varanasi: Kashi Sandesh, Kashi Taru, Kashi Prakash, Kashi Komal		
SAUs Varieties:		
Hisar Shyamal	-	Tolerant to little leaf and resistant to bacterial wilt
Hisar Pragati	-	-
Hisar Jamuni	-	-
Pant Samrat	-	Tolerant to shoot and fruit borer and resistant to BW
Pant Rituraj	-	-
MDU-1	-	Purple colour
Annamalai	-	Aphid resistant
KKM-1	-	White colour, Suitable for diabetic patient
PKM-1		Drought tolerant and suitable long distance transport
Other varieties: CO-1 CO-2, VRM-1, PLR (BR-2), PPI-1, MD… …hma, Phule Harit, Phule Arjun		
F_1 hybrids:		
Pusa Anmol	PPL × Hyde…	
Pusa Hybrid -5	Sel N…	

Pusa Hybrid-6	Sel Br-112 × Sel 91-2	-
Pusa Hybrid-9	Sel 91-2-1×Sel 190-10-12	-
Arka Navneeth	IIHR 22-1× Supreme	-
Arka Anand	-	Resistance to bacterial wilt, suitable for kharif and rabi
Arka Neelkanth (BWR-54)	-	Resistant to bacterial wilt
Pant Brinjal Hybrid-1	-	-
Hybrids: COBH-1, COBH 2		

Important variety with features:

- ★ Resistant to *Fusarium wilt:* Florida Market
- ★ Suited for ratoon cropping: Hissar Jamuni
- ★ Bacterial wilt resistant varieties: Pusa Purple Cluster, Annamalai
- ★ Resistant to *Phomopsis* fruit rot: Pusa Bhairav, Pusa Anupam, Florida Market
- ★ Soft joint and is easy to harvest: NDB-25

3. CHILLI

3. Chilli: *Capsicum annuum:* 2n=2X=24: Origin: Tropical America
- ★ *Capsicum* species, commonly known as peppers
- ★ Used as a fresh vegetable
- ★ Pickles, sauces and powders represent the major processed pepper products of the industry
- ★ Paprika: Pepper powder
- ★ Fresh sauce: Salsa sauce
- ★ Chilli tolerate extremes of climate than tomato and brinjal
- ★ Capsicum is an important crop grown worldwide as a vegetable and spice crop
- ★ In chilli severe fruit drop and poor fruit set occur when temperature beyond 40°C
- ★ Chilli flower drop is highest at >35°C
- ★ Low light temperature (8-10°C and 15°C) increases the fruit set and develop as parthenocarpic fruits
- ★ Rich in vitamin-A and C than tomato (Vitamin-A: 870 IU/100g and Vitamin-C: 321 mg/100g)
- ★ In food and beverage industries chilli is used in the form of oleoresin which permits better distribution of colour and flavour in food

- ★ Green chilli rich in rutin (Used for pharmaceutical use)
- ★ Major pigment in red fruit colour: capsanthin and capsorubin
- ★ Yellow fruit colour: lutein, Orange fruit colour: β-carotene
- ★ Chilli richest source of thiamine followed by peas
- ★ Chilli is the richest source of fiber (6.8 g/100g)
- ★ Percentage of capsanthin colouring matter: 36%
- ★ Formula for capsanthin: $C_{40}H_{56}O_3$
- ★ Paprika: non pungent red colour chilli powder (colour is the principle value)
- ★ Pungency of chilli fruit due to presence of Capsaicin (N-vanillyl-8-methyl-6-E-noneamide)
- ★ Capsaicin is present in cores or septa walls and a placenta
- ★ Formula for capsaicin: $C_{18}H_{27}NO_3$
- ★ Capsaicin is the condensation product of 3-hydroxy-4-methodxybenzylamine and decyclenic acid, which produces a highly irritating vapour on heating
- ★ Capsaicinoids are mainly synthesized from the glandular epidermal cells of the placenta
- ★ Most important chilli growing state in India: Andhra Pradesh (Rainfed crop-Dry chilli)
- ★ Highest productivity state in India: Andhra Pradesh
- ★ India is the major producer, consumer and exporter of chilli in the world
- ★ Major chilli growing period in South India: June-October
- ★ The heterosis in chilli: 20-50%, suitable for exploitation of F_1 hybrids

Important species:

- ✦ Total domesticated *Capsicum* species: 5

Special features	Scientific name
Most of small highly pungent chilli	*Capsicum frutescens* (Tabasco or Bird pepper/Perennial chilli)
Purple flowering species	*C. pubescens, C. eximium, C. cardensii*
White flowering species	*C. annum* and *C. baccatum*
Yellow anther species	*C. baccatum*
Black seed colour species	*C. pubescens*
Powdery mildew resistance species	*C. pubescens, C. microcarpum*
Anthracnose resistant species	*C. chinensis* *C. baccatum* (wide spectrum resistance)
Highest pungent hottest chilli in the world	Bhoot Jolokia/Naga King chili ... North East India

- ★ Pungency of chilli is measured by Scoville Heat Units (SHU)
- ★ The Scoville scale, invented by Wilbur S... 1912, pungency

★ Highest pungency chilli: Bhut Jolokia (India): 10,01,304 SHU, Lowest pungency: Bell pepper
★ Chilli and capsicum classified as often cross pollinated crop
★ Cross pollination percentage in chilli about 63%
★ Pollination agents: Bees
★ Type of fruit: Multi-seeded berry
★ Seed rate: 1-1.5 kg/ha
★ Seed viability: 2 years
★ Main planting season of chilli: June-July
★ Generally yield of green chilli is 3-4 times higher than dry chilli
★ 100 kg of ripe fruits gives a 25-40 kg of dry chilli
★ Chilli ripe fruit drying temperature: 54.4°C for 2-3 days

Purpose	Irrigated crop	Rainfed crop
Green chilli	7.5-10t/ha	1.5-2.5t/ha
Dry chilli	2-2.5t/ha	0.5-1t/ha

★ Isolation distance for hybrid seed production: 400 m
★ Female: Male ratio for seed production: 2:1
★ A line: Male sterile line, B line: Maintainer line (Male fertile)
★ Average F_1 hybrid seed yield: 300-350 kg/ha (10-15 g/plant)
★ Seed extraction method for commercial scale: maceration
★ Most harmful species of nematode for chilli crop: *Meloidogyne arenaria*

Varieties of chilli:

Varieties	Breeding methods	Specific features
Paprika cultivars:		
Bydagi, Warangal Chilli, Arka Abhir, Kt. 19		
Chilli:		
Pusa Jwala	NP-46A × Puri Red	Tolerant to thrips, mites and aphids
Pusa Sadabahar	Pusa Jwala × IC 31339 (*C. frutescens*)	Resistant to CMV, TM V and leaf curl viruses
Pant C-1	NP-46A × Kandhari (Natural cross)	Tolerant to mosaic and leaf curl virus
Punjab Lal	Perennial × Long Red	Rich in capsaicin (0.7%) and resistant to TMV
G-2	Indigenous bulk of NP-46A	
G-3		
G-4 (Bhagyalakshmi)		
G-5 (Andhra Jyoti)		
CO-3	-	Cherry type fruits
Arka Suphal	Resistant to powdery mildew	Dual purpose
Arka Lohit	Tolerant to powdery mildew, suitable for both irrigated and rainfed cultivation	
F_1 Hybrids:		
Arka Sweta	CGMS based hybrid	
Arka Meghana	CGMS based hybrid	
Arka Harita	CGMS based hybrid	Tolerant to powdery mildew and viruses
CH-1- PAU	MS-12 × LLS	
CH-3- PAU	MS-12 × S-2530	
Kashi Surkh	CGMS line (CCA-4261) × Pusa Jwala	Suitable for green as well as dry fruit
Kashi Ageti	-	
Kashi Tej	CGMS	
Kashi Early	CGMS line	
Konkan Kirti	NP 46-1 x JCA 154	Suitable for export
Other varieties: PKM-1, PMK-1, MDU-1, CO-1, CO-2, K-1, K-2		
MPKV, Rahuri: Phule Jyoti, Phule Mukta; HAU, Hisar: Hisar Shakti , Hisar V		
Mutant variety:		
MDU-1	Gamma ray mutant of K-1	

Special features of variety:
★ Kashi Anmol: popular in the Indo-Gangetic Pl
★ VNR-332 (Rani) a notified commercial hot p
★ Resistant to mosaic disease: Puri Red

★ Tolerant to spodoptera leaf eating caterpillar, mites and aphids: Punjab Lal
★ Suitable for HDP with low pungency and resistant to virus: Jawala Mukhi
★ Tolerant to thrips: NP-46A
★ Yellow anther type and resistant to thrips and mites: Bhaskar
★ Bacterial wilt resistant variety: Utkal Reshmi
★ Multiple disease resistance variety: Punjab Surakh
★ Suitable for colour extraction: Arka Abhir, Punjab Lal
★ Paprika variety, suitable for powder and good for export: *Kt-19*

4. CAPSICUM

4. **Capsicum:** *Capsicum annum:* 2n=2X=24: Origin: Tropical America
★ Sweet pepper is also known as *Shimla Mirch*
★ Capsicum has bidirectional root system
★ Himachal Pradesh is the leading supplier of capsicum in offseason for new delhi
★ China is the major producer of capsicum in the world
★ The first F_1 hybrid of capsicum : Bharat, Indo American Hybrid Seeds, Bangalore, 1973

Varieties of capsicum:

Varieties	Breeding methods	Remarks
Sweet Banana	-	-
California Wonder	-	-
Yolo Wonder	-	-
Arka Mohini	Introduced from USA	
Arka Gaurav	Introduced from USA	Tolerant to bacterial wilt
Arka Basant	Introduced from Hungary	-
King of North	-	-
Pusa Deepti	Yolo Wonder × Russian Yellow	F_1 Hybrid
Kt-1	-	
IAHS: Bharat	-	1st F1 hybrid (1973)

Major pest and diseases in chilli:

Diseases	Casual organism	Vector
Anthracnose/Dieback/Fruit rot	Fungi- *Colletotrichum capsici*	Seed borne disease, fruit yield losses >80%
Fruit and root rot, and shoot blight	*Phytophthora capsici*	Soil borne disease
Frog eye leaf spot	*Cercospora capsici*	Most common nursery disease
Chilli leaf curl	Virus	Whitefly
Chilli mosaic	Virus	Aphids
Potyviruses		Emerging problem
Pest:		
Chilli thrips	*Scirtothrips dorsalis*	Transmitted chilli leaf curl disease
Physiological disorders:		
Blossom end rot (BER)	Excessive N_2 + Water stress	

Malvaceous Vegetable Crops

5. OKRA

5. **Lady's finger or Okra:** *Abelmoschus esculentus*: Malvaceae: 2n=2X=130: Origin: Tropical Africa
★ Warm season vegetable
★ Seed of okra will not germinate below 20°C
★ Okra, seed germination 25-35°C but fast germination observed at 35°C
★ Temperature above 42°C cause flower drop
★ Fruits rich source of iodine
★ Fruits rich source of calcium (66mg100g), potassium (103mg/100g) and Vitamin-C (30mg/100g)
★ Mucilage present in okra fruits is due to polysaccharides *i.e.* galacturonic and glucuronic acids
★ Oil content in okra seeds: 40%
★ Protein content in okra dried seed: 20-30%
★ India is the leading producing country in the world (72%

- Highest productivity: Chhatishgarh
- National average productivity: 11.9 Mt/ha
- Major Okra growing states: West Bengal > Gujarat > Odisha
- Leading okra producer in the world: India (72.9%) > Nigeria > Sudan
- After onion okra accounts 70% of the 30% exchange earnings from export of vegetable
- Genus *Abelmoschus* was 1st established by Medikus in 1787
- Dr. Harbhajan Singh initiated systematic research work on improvement of okra in India
- Type of fruit in okra: Capsule
- No inbreeding depression in okra
- Widely reported chromosome number in okra: 2n=130
- Cultivated okra is a polyploidy in nature
- Cultivated okra *Abelmoschus esculentus* is a natural amphidiploid (2n=130)
- 3 species are cultivated form: *Abelmoschus esculentus, Abelmoschus manihot* and *Abelmoschus moschatus*

Features	Botanical name
Progenitor of cultivated okra, Origin: North India (UP)	*Abelmoschus tuberculatus* (2n=58)
Putative ancestor of okra	*Abelmoschus tuberculatus*
Guinean okra/ West African okra	*Abelmoschus callei*
Guinean okra is a natural amphidiploid between	*A. esculentus* × *A. manihot*
Ghana okra (Complex poly species)	*Abelmoschus manihot*
Highest chromosome okra species	*Abelmoschus manihot* ssp. *manihot* (2n=194)
Symptomless resistance to YVMV	*Abelmoschus tuberculatus*
Immune to YVMV	*Abelmoschus manihot var. manihot*
True resistance to YVMV	*Abelmoschus pungens*
Cultivated for aromatic seeds	*Abelmoschus moschatus* (Ambrette)
Tolerant to shoot and fruit Borer (*Earias spp.*)	*A. tuberculatus, A. caillei*, cv. *Narnaul Special*
Resistance to low temperature and frost	*A. angulosus*

- Facultative autogamy type
- Okra is classified as often cross pollinated crop due to presence of protogyny
- Natural cross pollination is about 5-12%
- Seed rate:
  - Summer season crop: 18-20 kg/ha
  - Rainy season crop:10-12 kg/ha
- Seed viability: 2 years
- Okra pods become ready for 1st harvesting after 45 days of sowing
- Best time of picking being 6-7 days after opening of flowers
- Post harvest treatment of CCC @ 100 ppm enhances shelf life of okra
- Export standard length: 6-8cm long
- Isolation distance for foundation seed: 400 m and certified seed 200 m
- Okra seed yield: 1200-1500 kg/ha
- Seed shattering is a major problem for okra seed production

Pest and diseases:

- Shoot and fruit borer (*Earias vittella*) is the most common occurring pest in okra
- Most devastating disease of okra: Yellow Vein Mosaic Virus (YVMV): Vector: Whitefly (*Bemisia tabaci*)
- Yield loss in okra due to YVMV is 50-90%
- *Abelmoschus manihot ssp. manihot* and *Abelmoschus tuberculatus* are tolerant to YVMV
- Powdery mildew (*Erysiphe spp.*) is the major problem in Southern India
- Enation leaf curl is a viral disease of okra,1st reported at IIHR, Bangalore in 1984
- Okra Enation Leaf Curl Virus (OELCV) is serious disease in north India. Transmission: white fly
- 'B' biotype whiteflies is contributing to epidemics of begomoviruses in okra
- Bt okra: Resistant to shoot and fruit borer (*Earias spp.*) gene: Cry 1Ac
- Bt okra in India: MHYCO
- Resistant to YVMV transgenic (Coat protein gene)

Varieties of okra:

Varieties	Breeding methods	Special features
1. Selection		
Perkins Long Green	Introduced from USA	Suitable for hills only
Harbhajan	Selection from Perkins Long Green	Suitable for hills only
Azad Kranti	Selection	Resist
Hisar Naveen	-	Resi
CO-1	Selection from 'Red Wonder'	
Pusa Makhmali	Selection form West Bengal	Suitable for mmer

Pusa Sawani (1962)	Pusa Makhmali × IC-1542	Tolerant to salinity, spineless, day neutral variety
2. Interspecific hybridization:		
Pusa A4	*A. esculentus* × *A. manihot ssp. manihot*	Tolerant to Jassids, fruit and shoot borer
Punjab-7	Pusa Sawani × *A. manihot ssp. manihot* (Ghana)	Resistant to YVMV
Punjab Padmini	Reshmi × *A. manihot ssp. manihot* (Ghana)	Resistant to YVMV
Parbhani Kranti	Pusa Sawani × *A. manihot*	Resistant to YVMV
Arka Anamika	*A. esculentus* × *A. tetraphyllus*	Resistant to YVMV
Arka Abhay	*A. esculentus* × *A. tetraphyllus*	Resistant to YVMV and tolerant to fruit borer
3. Intervarietal hybridization:		
Varsha Uphar	Lam Selection-1 × Parbhani Kranti	Resistant to YVMV and tolerant to leaf hopper
Hisar Unnat	Selection 2-2 × Parbhani Kranti	Resistant to YVMV
4. Mutant varieties:		
Parbhani Tillu	Induced mutant	Suitable for processing
Punajb-8 (EMS-8)	Induced mutant of Pusa Sawani treated 1% EMS	Resistant to YVMV and tolerant to fruit borer
MDU-1	Induced mutant of from gamma irradiation treatment of Pusa Sawani	Suitable for dehydration
CO-2	AE 180 × Pusa Sawani	Resistant to YVMV and suitable for growing in kharif and summer season
CO-3	Parbhani Kranti × MDU-1	

Important varieties with features:

- Varieties of okra suitable for export: Pusa A-4, Parbhani Kranti, Varsha Uphar
- Suitable for ratooning crop: Arka Abhay and Pusa A-4
- **Public sector okra F_1 Hybrids:** Shitla Uphar, Shitla Jyoti, Kashi Bhairav, Kashi Mahima
- **IIVR, Varanasi:** Kashi Pragati, Kashi Vibhuti, Kashi Kranti
- **Other varieties:** Phule Utkarsha, CO-1, 2, 3, , 3
- **Private sector popular hybrids:** Panchali, Adhunik, Supriya, Varsha

D. Cruciferous Vegetable Crops / cole

1. **Cabbage**
2. **Cauliflower**
3. **Knol-Khol**
4. **Sprouting Broccoli**
5. **Brussels Sprouts**

★ The word 'cole' is abbreviated from 'Caulis' means stem

★ Cole crops has 6 major horticultural types

Cole crops	*Scientific name*	Chro. No.	Economic part
1. Cabbage	*Brassica oleracea* var. *capitata*	2n=2X=18	Modification of terminal bud
2. Brussels sprouts	*Brassica oleracea* var. *gemmifera*	2n=2X=18	Enlargement of axillary bud
3. Cauliflower	*Brassica oleracea* var. *botrytis*	2n=2X=18	Modification of inflorescence
4. Broccoli	*Brassica oleracea* var. *italica*	2n=2X=18	Modification of inflorescence
5. Knol-Khol	*Brassica oleracea* var. *gongylodes*	2n=2X=18	Swollen stem
6. Kale	*Brassica oleracea* var. *acephala*	2n=2X=18	Modification of leafy organs

★ Cole crops belongs to the family "Brassicaceae" under order '*Papaverales*'

★ Language: Cauliflower-Latin; Knol-Khol- German; Broccoli-Italian

★ Cauliflowers, Cabbage, Brussels sprouts, Knol-khol, Kale, and Broccoli are related and have originated from common ancestor, wild cabbage/Coleworts (*Brassica oleracea* var. *sylvestris*)

★ Cauliflower is the only crop in group of cole crops in which the intermediate stage of curding lies between vegetative and reproductive stage

★ Excessive use of cole crops induce in swelling of thyroid glands and goitre disease

★ Highest vitamin-A: 1st Kale (20, 00 IU/100g), 2nd Sprouting broccoli (9000 IU/100g)

★ Highest vitamin-C: 1st Kale (187 mg/100g), 2nd Brussels sprout (185 mg/100g)

★ Cultivation of broccoli and Brussels sprouts started in 19th century

★ Cole crops are biennial does not bear 2nd year's life cycle but it indicates the 2 seasons 1. Vegetative stage 2. Reproductive stage

★ Leading cauliflower and broccoli producer in the world: China > India (37.5%) > Italy

★ Cole crops are biennial for seed production and annual for consumptive use
★ Cole crops need chilling requirement for inflorescence emergence

Crops	Chilling temperature	Weeks
Cabbage	4-10°C	6-8
Brussels sprouts	4-10°C	4-6
Knol-khol	7-10°C	5-7

★ Absence of chilling plants are continue their vegetative stage
★ Cole crops are calcicole (grown in chalk soils)
★ Cole crops are highly heterozygous and heterogeneous in nature
★ Cole crops are highly cross pollinated crop due to protogyny and self incompability
★ Main pollinating agents: Honey bees and flies
★ Among the cole crops, highly cross pollinated crop: Broccoli- 95% followed by Knol-Khol-91%, cabbgag-73%, Brussels sprout- 72%
★ Tetradynamous is the special anther type feature of cole crops
★ Special kind of pod or type of fruit in cole crops: Siliqua
★ All 6 cole crops intercrossable: Produce normal fertile hybrids
★ New vegetable "Hakuran" from Brassicaceae
  ✦ Derived from interspecific hybridization between Cabbage × Chinese cabbage by embryo culture
  ✦ Resistant to bacterial soft rot, drought and heat
  ✦ New leafy vegetable most commercially used in Japan
★ Other interspecific hybrids derived from Brassicaceae
  ✦ Nabicol: Kale × Turnip
  ✦ Caulicob: Cabbage × Cauliflower
  ✦ Swede: Turnip × Cabbage: Cruciferous root vegetable
  ✦ Raphanobrassica: Radish × Cabbage

Self incompatibility in cole crops:

✦ Promotes out crossing
✦ Inability of a fertile hermaphrodite plant to produce zygotes after self pollination
✦ 1st reported in cole crops by Bateman (1954)
✦ Sporophytic SI is commonly found in *Brassicaceae* vegetables
✦ Sporophytic SI is controlled by single locus with >50 alleles
✦ SI is due to glycoprotein (S-locus glycoprotein) (SLG)
✦ Strongest SI in cole crops: Kale

★ Weakest SI in cole crops: Winter type of cauliflower in Europe (Indian cauliflower-Early types)
★ Maintenance of self incompatibility or overcome the SI by
  ✦ Bud Pollination: Commonly used by breeders
  ✦ CO_2 (2-5%) treatment: Used in commercial seed production
  ✦ NaCl (3%) spray
★ Book 'Cole crops' written by Nieuwhof
★ Genetic constitution of cole crops: CC genome (2n=2X=18)
★ Cytodeme means a gene pool of a cultivated species (Sharing a same chromosome number and intercrossable)
★ Cytodeme concept was given by Harberd (1972)
★ Cytodeme of Brassica oleraceae consist of 6 cultivated vegetables and 9 wild relatives
★ Brassica U's triangle given by "Nagaharu U" (1935)

1. CABBAGE

1. **Cabbage:** *Brassica oleracea* var. *capitata*: Brassicaceae: 2n=2X=18: Origin: Mediterranean region
   ★ Cabbage is more hardy than cauliflower and can withstand frost and extreme cold weather
   ★ Cabbage is shallow rooted crop
   ★ Edible part of cabbage: Head
   ★ The term head is used for cabbage and lettuce
   ★ Chinese cabbage and kale are resistant to downy mildew
   ★ India rank 3rd in cabbage production
   ★ Leading cabbage producer in the world: China > India (12.8%) > Russia
   ★ Cabbage F_1 hybrids occupy 85% of cabbage cultivated area in India
   ★ Highest productivity: Madhya Pradesh
   ★ National average productivity: 22.6 Mt/ha
   ★ Major Cabbage growing states: West Bengal > Orissa > Bihar
   ★ Cabbage hybrids are popular due to heat tolerance, uniformity, field staying capacity, strong SI system for hybrid seed production
   ★ Head compactness is determined by Pearson formula: $Z = (C \times 100)/W^3$
   ★ Japan is the 1st country who developed cabbage hybrid and Nagaoka was the 1st hybrid released from Japan (1951)
   ★ Flavour in cabbage leaves is due to the glucoside "Sinigrin"
   ★ Cabbage juice remedy for poisonous mushroom
   ★ Sauerkraut is fermented product of shredded cabbage

★ Sauerkraut has a curative effect on scurvy diseases

★ Cabbage has anti-cancer property, due to the presence of Indole-3-Carbinol

Important species:

Common name	Botanical name
White cabbage	*Brassica oleracea* var. *capitata* f. *alba*
Red cabbage	*Brassica oleracea* var. *capitata* f. *rubra*
Savoy cabbage	*Brassica oleracea* var. *capitata* f. *sabauda*
Wild cabbage/Colwort/Progenitor of cabbage	*Brassica oleracea* var. *sylvestris*

★ White cabbage and round type of cabbage is grown commercially in India

★ Round head types are the earliest followed by conical types

★ Conical head variety: Jersey Wakefield

★ Seed rate:

- ✦ Early varieties: 500 g/ha
- ✦ Late varieties: 375 g/ha

★ Cabbage is highly cross pollinated crop

★ Degree of cross pollination is 73%

★ Flowers of cabbage: Protogynous

★ Cabbage requires for flowering specific low temperatures for chilling 4-8°C for 40-60 days

★ Generally thick and waxy leaved varieties/hybrids are suitable for high temperature

★ White and Savoy cabbage- C_6 salt index

★ Red cabbage -C_4 salt index

★ Salt index is a measure of the salt concentration as number of grams of sodium chloride per litre of soil moisture

★ To control seed borne disease of cabbage, hot water treatment of seeds @ 50°C for 30 min

★ *Cry 1A* class is useful gene resistance against cabbage butterfly and diamond back moth cabbage

★ Optimum range for growth and head formation in cabbage: 15-20°C

★ Optimum temperature seed germination of cabbage: 12-16°C

★ Spray of CCC or SADH 2500-5000 ppm increases the low temperature resistance in cabbage

Methods of seed production in cabbage:

- ✦ Seed to seed method (*in situ*): Practised for production of foundation and certified seed
- ✦ Head to seed method (3 types): Only for nucleus and breeder seed production

- ✦ Head intact method
- ✦ Stump method: Higher seed yield
- ✦ Stump with central core intact method
- ✦ Late planting: Recommended for certified seed production

★ Spraying 50ppm of boric acid at flowering enhance the seed yield

★ Cabbage seed yield: 500-650 kg/ha

★ Storage temperature of cabbage: 0°C and 90-95% RH for 2-8 months

★ Cabbage yellows is caused by *Fusarium oxysporum* f. *conglutinans*

★ Black leg/dry rot of cabbage is caused by fungus *Phoma lingum*

★ Black leg diseases more commonly occurs in saline soil

Varieties of cabbage:

Varieties	Breeding methods	Special features
Golden Acre	Selection from EC-6774 (Japan)	-
Drumhead Savoy	-	Blistered or wrinkled leaf variety
Pusa Drum Head	Flat head type	Resistant to black leg, largest head variety
Pusa Mukta (Sel.8)	Selection from EC-24855 x EC-10109	Resistant to black rot
Pusa Ageti	-	1st tropical variety in India
Pusa Sambandh	Synthetic variety(Pusa Synthetic)	Suitable for HDP, wider adaptability, early maturing
September	Introduction from Germany	Popular in Nilgiri hills
Pride of India	-	-
Copenhagen Market	-	-
KGMR-1 (F_1 hybrid)	83-1-621 × GA-111	Better staying capacity in the field

★ Red cabbage variety: Red Acre

★ Savoy cabbage variety: Chieftain

★ Exotic hybrids marketed by NSC: Green Express and Green Boy

★ Tolerant to high temperature: KK Cross, Summer King, Green Express

2. CAULIFLOWER

2. **Cauliflower:** *Brassica oleracea* var. *botrytis:* Brassicaceae: 2n=2X=18: Origin: Mediterranean region (Cyperus)

- ★ The name cauliflower has originated from latin word 'Caulis' (cabbage) and 'Flora' (Flower)
- ★ Cauliflower curd is a prefloral fleshy apical meristem
- ★ Thermosensitive crop
- ★ Edible part of cauliflower is known as "curds"
- ★ Cauliflower was introduced to India in 1822 by Dr. Jemson
- ★ India is the largest producer of cauliflower in the world
- ★ In India cauliflower is classified into 4 groups
  - ★ Highest productivity: West Bengal
  - ★ National average productivity: 19.6 Mt/ha
  - ★ Major cauliflower growing states: West Bengal > Bihar > MH
- ★ Cauliflower has descended through mutation and selection from wild cabbage
  - ✦ Ancestor of cauliflower: *Brassica cretica*
- ★ The present day Indian Cauliflower developed as results of intercrossing between *European and Cornish types*
- ★ Cauliflower is a monogenomic species whose genomic constitution is 'CC'
- ★ Cauliflower curd formation is due to 2 mutant genes: *BoAP1-a* and *BoCa-1-1*
- ★ Orange cauliflower: Rich in β-carotene ('*Or*' gene)
- ★ Major difference between cauliflower and broccoli is cauliflower lack of axillary branching habit
- ★ Type of inflorescence: Racemose
- ★ Fertility index (FI): used to determine the self-compatible (SC) or self-incompatibility (SI) lines
- ★ FI: >2 SI line, <1 SC line, 1-2 Pseudo-SI line
- ★ Ealry Indian Cauliflower and winter cauliflower (Europe) shows high level of self-incompatibility
- ★ Early cauliflower and Sprouting Broccoli are annual in nature
- ★ Late type-Snowball (self-blanching growth habit)
- ★ Seed rate:
  - ✦ Early crop: 500-600 g/ha
  - ✦ Mid and late crops: 350-400 g/ha
- ★ Optimum temperature for curd initiation is 17-20°C

- ★ At high temperature above 25°C in most of the cultivars, the curds are small, loose and creamish or yellow in colour
- ★ Common herbicide used in cabbage: Basalin (3.3 lit/ha)
- ★ Blanching is common practice in cauliflower for protect curd from yellow colour after their direct exposure to sun and to arrest enzymatic activity
- ★ Scooping is special operation done in cauliflower for initiation of flower stalk eg. Darjeeling hills in West Bengal
- ★ Scooping means removal of central portion of curd for easy initiation of flower stalk
- ★ Storage temperature: 0°C and 90-95% RH for 2-4 weeks
- ★ Black rot and black leg: to control seed treatment done with hot water at 50°C for 25-30 minutes

Varieties of cauliflower:

Early		Mid-Early	Mid-Late	Late
Curd initiation and development temperature:				
Early I: 20-27°C	**Early II:** 20-25°C	16-20°C	12-16°C	10-16°C
Pusa Kartiki	Pusa Deepali	Pusa Hybrid-2	Pusa Betakesari	Pusa Snowball-1
Pusa Karthik Sankar	Pusa Katki	Pusa Sharad	Pusa Himjyoti	Pusa Snowball-2
Pusa Meghna		Improved Japanese	Pusa Shubhra	Pusa Snowball-K1
Pusa Early Synthetic		Pant Gobhi-4	Pusa Paushija	Pusa Snowball-16
Arka Kanti		Pant Shubra	Pusa Shukti	Ooty-1
Kashi Kunwari			Pant Shubhra	
			Pusa Synthetic	
			Hisar-1	

F_1 Hybrids	Parents	Remarks
Pusa Hybrid-2	CC-35× 18-19	Field resistance to downy mildew
Pusa Kartik Sankar	CC-14 × 41-5	Resistant to downy mildew

Special features of important varieties:

- ★ Pusa Betakesari: orange colourd (β-carotene) cauliflower variety (mid-late group)
- ★ Self- blanched variety of cauliflower: Pusa Deepali
- ★ Self-blanched and offseason variety: Pusa Himjyoti and Hisar-1
- ★ Tolerant to curd and inflorescence blight: Pusa Synthetic
- ★ Highly resistant to black rot and free from riceyness: Pusa Katki
- ★ Resistant to black rot, curd and inflorescence blight: Pusa Shubhra and Pusa Snowball K-1
- ★ Resistant to black rot: Pusa Snowball K-1
- ★ Tropical cauliflower variety from IIHR: Arka Kanti
- ★ Synthetic variety: Pant Gobhi-3

Physiological disorders of cauliflower:

Disorders	Symptoms	Reasons
Riceyness	Premature initiation of floral buds on upper surface of curds	Excess N_2, Fluctuation in temperature and high humidity
Fuzziness	Velvety appearance of pedicels	Cultivation in abnormal time
Blindness	Without terminal bud & fail to form curd	low temperature (Frost) or injury by insects and pests
Leafyness	Small green leaves in the curds	High temperature
Buttoning	Development of small curds in young plant	low N_2, high temperature and planting of early varieties
Hollow stem	-	Excess N_2
Whip tail	Mid rib development	Mo deficiency, Common in acid soil
Chlorosis	-	Mg deficiency
Browning/Red rot/Brown rot	-	Boron deficiency

3. KNOL-KHOL

3. **Kohlrabi:** *Brassica oleracea* var. *gongylodes*: Brassicaceae: 2n=2X=18: Origin: Mediterranean region

- ★ Cool season crop
- ★ Kholrabi is the German name for cabbage-turnip
- ★ Edible part of knol-khol is swollen stem called "tuber" or "Knob"
- ★ Stem tuber or knobs are developed above the ground level
- ★ Knol-Khol is originated from wild cabbage (*B. oleracea* var. *sylvestris*)

- ★ Purple/Early varieties are more susceptible to premature bolting
- ★ In India, knol-khol is more popular in Kashmir
- ★ In Kashmir, knol-khol leaves are also used as greens
- ★ Best time of planting: October
- ★ Type of inflorescence: Racemose
- ★ Seed rate 800-1000 g/ha
- ★ Early varieties of knoll-khol are more prone to premature bolting
- ★ Purple varieties are more susceptible to premature bolting
- ★ **Important varieties**: White Vienna, Purple Vienna, Early White Vienna, King of North, Large Green
- ★ White Vienna is most popular early variety
- ★ **New variety**: Palam Tenderknob, Pusa Virat
- ★ Storage temperature: 0°C and RH 95-100% for 25-30 days

4. SPROUTING BROCCOLI

4. **Sprouting Broccoli:** *Brassica oleracea* var. *italica* Brassicaceae: 2n=2X=18: Origin: Mediterranean region

- ★ Broccoli is a cool season crop
- ★ Broccoli is an Italian word derived from Latin 'Brachium' means an arm or branch
- ★ Broccoli refers to young shoots
- ★ USA is the leading producer of sprouting broccoli
- ★ Broccoli grown in India is commonly known as "green sprouting broccoli" or "calabrese"
- ★ In India sprouting broccoli is widely grown in Himachal Pradesh
- ★ Broccoli improvement in India is carried out by Dr. Pritam Kalia, IARI
- ★ In India green type cultivars are more commonly cultivated than other type
- ★ Broccoli is an important health food as it has to be anticarcinogenic and antioxidant
- ★ Sprouting broccoli has 130 times more vitamin A than cauliflower and 22 times more than cabbage
- ★ Sprouting broccoli is a rich source of 'sulphoraphane' (Anticancer property)
- ★ Heading broccoli is highly nutritive and it contains 3.3% protein
- ★ Most nutritive type of broccoli: Green type of broccoli
  - ✦ Chinese Broccoli: *Brassica alboglabra*
  - ✦ Source of high glucoraphanin content: *Brassica villosa*
- ★ Type of inflorescence: Cymose
- ★ Seed rate: 400-500 g/ha

★ Broccoli harvest when before buds open
★ Sprouting Broccoli for optimum temperature of 12-18°C is suitable for proper head development
★ Temperature for Brussels sprouts and Sprouting Broccoli seed germination is 12-16°C
★ Yellowing of broccoli is a problem in storage
★ Yellowing of broccoli is delayed by 1-MCP
★ Storage temperature: 0°C and 95-100% RH for 2-4 weeks

Varieties of broccoli:

New Varieties	Head colour	Other features
Palam Kanchan	Yellowish green (Heading Broccoli)	-
Palam Vichitra	Purple (Heading Broccoli)	-
Palam Haritika	Green (Sprouting Broccoli)	-
Palam Samridhi	Green (Sprouting Broccoli)	Early maturing variety
Pusa KTS-1	Sprouting Broccoli	
Italian Green	-	-
Green Head	-	-
Punjab Broccoli	-	-

Important features of varieties:

★ Palam Samridhi variety of sprouting broccoli is mainly recommended for subtropical cultivation
★ Bronzino is a purple variety of heading broccoli type
★ Calabrese type broccoli developed from Italian Green sprouting broccoli
★ Purple Sicilian broccoli is also known as purple cauliflower
★ De Cicco is main winter broccoli

5. BRUSSELS SPROUTS

5. **Mine cabbage/Brussels sprouts:** *Brassica oleracea* var. *gemmifera*: Brassicaceae: 2n=2X=18:
Origin: Mediterranean region
★ Cool and moisture loving, frost resistant crop
★ Edible part: Swollen axillary bud (sprouts or buttons or mini cabbage)
★ **Varieties:**
✦ Tall cultivar: Hilds Ideal, Amagar Market and Danish Prize, Rubine

✦ Dwarf cultivar: Catskill, Early Dwarf, Dwarf Gem and Long Island Improved
★ Hilds Ideal is suitable variety to Northern Plains and Hills
★ Jade Cross: F_1 hybrid of Japan- Early short stemmed hybrid
★ Rubine and Hilds Ideal introduced variety is recommended by IARI
★ Genetic male sterility was reported in Brussels sprouts by Johnson in 1958
★ Brussels sprouts have sporophytic SI
★ Topping is done to increase harvesting time
★ Loose sprouts marketed as a 'blowets'
★ Excess application of potash imparts bitter taste to sprouts
★ Storage temperature: 0-1°C and 90-95% for 3-5 weeks
★ **Kale:** Lutein rich vegetable: 9.8-13.4 mg/100g of fresh weight

Diseases of cole crops:

Diseases	Casual organism	Remarks
Club root of cabbage	*Plasmodiophora brassicae* (Fungus)	Most prevalent in acid soils
Downy mildew	*Hyaloperonospera parasitica*	Serious disease in young plants
Black rot	*Xanthomonas campestris* pv. *campestris*	'V' shape chlorosis on margin of leaves, Seed borne
Curd rot/Soft rot	*Erwinia carotovora*	Most destructive disease during storage
Stalk rot	*Sclerotonia scleratium*	Major problem in seed production
White rust/White blisters	*Albugo candida*	Most common in acidic soil
Black leg/dry rot	*Fusarium spp.*	Seed borne disease
Soft rot	*Erwinia carotovora*	Destructive disease of storage
Pest of cole crops:		
Diamond back moth	*Plutella xylostella*	Most damaging pest
Stem borer	*Hellula undalis*	-

Important other crucifer vegetables:

Cruciferous vegetables	
Cury kale	*Brassica oleracea* var. *acephala* sub var. *lacinata*
Smooth leaved kale	*Brassica oleracea* var. *acephala* sub var. *plana*
Thousand head kale	*Brassica oleracea* var. *acephala* sub var. *milicapitata*
Tree kale	*Brassica oleracea* var. *acephala* sub var. *palmifolia*
Marrow stem Kale	*Brassica oleracea* var. *acephala* sub var. *medullosa*
Chinese kale	*Brassica oleracea* var. *alboglabra*
Collards	*Brassica oleracea* var. *sabellica*
Kitchen Kale/Curly Kale	*Brassica oleracea var. fimbriata*
Pe-tsai/Chinese Cabbage	*Brassica pekinensis*
Pak-choi/Chinese Cabbage	*Brassica chinensis*
Swede /Rutabaga	*Brassica napus var. napobrassica*

E. Cucurbitaceous Vegetable Crops

1. Cucumber
2. Musk melon
3. Water melon
4. Round melon
5. Bittergourd
6. Bottlegourd
7. Snakegourd
8. Pointed gourd
9. Ashgourd
10. Sponge gourd
11. Little gourd
12. Pumpkin and squashes
13. Chow-chow

General cucurbits:

- ★ Cucurbits is the largest group of summer vegetable crops
- ★ Cucurbits- term coined by Dr. Bailey
- ★ Cucurbits are generally richer in methionine than the legumes
- ★ Cucurbits are C_3 plants
- ★ *Cucumis* and *Cucurbita* have usually ordinary unsaturated acids like oleic and linoleic acids
- ★ Vegetative propagated Cucurbits: Parwal (Pointed Gourd), Chow-Chow, Kundsru (Ivy Gourd)
- ★ Bitter gourd rich in Vitamin-C (96 mg/100 g), Pumpkin containing high carotenoid, Kakarol high in protein (3.1%), Chow-Chow fairly high in Calcium (140 mg/100g)
- ★ Meta-xenia common in cucumber and bottle gourd
- ★ Bitter pollen or foreign pollen fertilizes the non-bitter or normal ovule causes bitterfruit known as metaxenia
- ★ Bitter principle in cucurbits due to the presence of 'cucurbitacins' *i.e.* tetracyclic triterpenes
- ★ Cucurbitacins and terpene compounds are responsible for bitter taste and flavour
- ★ Watermelon is a highly cross pollinated crop due to separation of sex-monoecious and andromonoecious
- ★ Flowering in cucurbits generally starts 40-45 days after sowing (DAS)
- ★ Sex ratio in cucurbits: 25-30:1 or 15:1
- ★ Hermaphrodite is considered as primitive sex form in cucurbits
- ★ Long day and high temperature promotes male flower in cucurbits
- ★ 1st 4-6 nodes bear staminate flower than pistillate will appears in cucurbits
- ★ Staminate flower appear 7 days earlier than pistillate in cucurbits
- ★ Growth regulator application in cucurbits is done at 2-3 leaf stage

★ Generally in cucurbits to enhance the female flower production: Ethylene is used
★ Short day treatment 9 hrs: Female flower is more
★ Generally in cucurbits to enhance the male flower production: GA_3 is used
★ Long day treatment 16 hrs: Male flower is more
★ Pollination: entomophilous

1. CUCUMBER

1. **Cucumber**: *Cucumis sativus*: 2n=2X=14: Origin: India
★ Day neutral plant, Thermophilic crop
★ 1st sequenced vegetable crop
★ 2nd most widely cultivated cucurbit after watermelon
★ Prefers slightly low temperature than watermelon and muskmelon
★ Tolerates cooler weather than melons
★ It is cultivated either for fresh consumption as slicing cucumber, or as pickling cucumber for preservation, marinated with vinegar, salt, dill or other spices
★ Cucumber has narrow genetic base (3-8% polymorphism)
★ Most common sex form: Monoecious
★ Most favourable temperature for cucumber: 18-24°C
★ Temperatures required for the seed germination of cucumber ranges between 15-35°C
★ In cucumber bitterness in fruit is due to "cucurbitacins"
★ Chemically cucurbitacin is tetracyclic triterpenes
✦ Progenitor of cultivated cucumber: *Cucumis hardwickii*: 2n=14
✦ African horned cucumber *Cucumis metuliferus*
✦ West Indian Gherkin: *Cucumis anguria*
✦ Hedge hog or Teasel Gourd *Cucumis dispaceus*
✦ *Cucumis hystrix*: Resistant to downy mildew, gummy stem blight, virus and nematode
✦ Source of β-carotene (Orange fleshed) species: *Cucumis sativus* L. var. *xishuangbannanesis* (*Ore*)
✦ New synthetic species: *Cucumis* × *hytivus* 2n=2x=38, synthetic allotetraploid
☆ Derived from interspecific hybridization between (*Cucumis hystrix* × *Cucumis sativus*) through embryo culture and followed by chromosome doubling
☆ Genome: HHCC (Amphidiploid)
★ Beit alpha cucumber (shiny, smooth, pale green colour, cylindrical shape): originated in Israel and exported to European countries
★ Beit alpha cucumber: gynocious and parthenocarpic type, performs well under high and low ture

★ European cucumber: (thin skin, dark green colour, long narrow shape)
★ Asiatic/oriental/indian cucumber: small seed cavity thick flesh, prickly skin

Fresh market/slicing/salad cucumber
- Fruit shape- cylindrical with blocky or rounded ends
- Fruit length length/diamatere ratio: more than 4 (larger LD)
- Fruit skin colour: dark-green colour

Parthenocarpy (Seedless cucumber)
- Parthenocarpy is the ability to develop fruits without pollination
- Complex inheritance or incomplete dominant gene (*P*)

Pickling cucumber
- Fruit shape: cylindrical or tapered shape
- Fruit length length/diamatere ratio: 2.8 to 3.8 (smaller LD)
- Fermented organism in brine solution: *Lactobacillus sp.*

Gynoecious cucumber
- Produces only female flowers
- Male flowers artificially induced through $AgNo_3$- male and morphologically bisexual flowers in gynoecious lines
- Gynoecious in cucumber is controlled by single dominant gene (*F/Acr*)

★ 1st gynoecious F_1 hybrid, Pusa Sanyog, developed in India in 1971
★ Economic sex ratio of cucumber: 15:1
★ The expression of sex forms is controlled by a series of multiple alleles at the "F/M" locus interacting with genes controlling the photoperiodic reaction
★ Induction of parthenocarpy in cucumber: Choloroflurenol
★ Ethylene sex hormone affect the sex differentiation in cucumber
★ AVG induce only male flowers in cucumber
★ Seed rate: 2.5-4 kg/ha
★ Cucumber fruit yield reduction is due to crown fruit inhibition or 1st fruit inhibition
★ Xenia and metaxenia commonly occurs in cucumber
★ Xenia: Effect of genes from the male parent on the development of fruit or seeds
★ Metaxenia: Effect of pollen on fruit shape and other fruit characteristics
★ External fruit quality characteristics governed by 1-3 genes
★ The most effective method for the improvement of quantitative traits, such as yield in cucumber, may be recurrent selection.
★ Single-seed-descent, a modification of pedigree breeding

★ Development of inbred lines from an F_2 population in cucumber mostly breeders uses pedigree method

★ More stable female sex expression in F_1 hybrids: gynoecious × gynoecious and gynoecious × hermaphroditic

Pest and diseases:

★ Fruit fly is very serious pest of most of the cucurbitaceous vegetables

★ Cucumber mosaic is transmitted by aphids

★ Bacterial wilt of cucumber is caused by bacterium (*Erwinina tracheiphila*) transmitted by striped cucumber beetle

★ Gummy Stem Blight: *Didymella bryoniae*, resistance source- *C. hystrix*

★ Powdery mildew of cucumber: *Sphaerotheca fuligenea*

★ Angular leaf spot (bacterial disease) (*Pseudomonas lachrymans*)

★ Pillow is the physiological disorder of cucumber due to calcium deficiency

★ Chilling injury as a physiological storage disorder of cucumber when exposed to below 15°C

Varieties of cucumber:

Varieties	Breeding methods	Specific features
Japanese Long Green	Introduction from Japan	-
Straight -8	Introduction from USA	-
Pusa Uday	-	Suitable for throughout the year
Pusa Barkha	Extra early variety	Tolerant to high temperature, downy mildew
Swarna Ageti	-	Slicing type
Swarna Sheetal	-	Slicing type
DCH-1 and DCH-2	Tropical gynoecious hybrids	-
Himangi	-	-
Phule Shubangi	Poinsette × Kalyanpur Ageti	-
Sheetal	-	-
Pant Parthenocarpic Khira-2		Parthenocarpic variety
Pant Parthenocarpic Khira-3		Parthenocarpic variety
F_1 Hybrid:		
Pusa Sanyog	Japanese gynoecious line × Green Long Naples	-

★ Downy mildew resistant cucumber varieties: Palmetto, PR-27, Santee and Palomar

★ Cucumber mosaic resistant varieties: Shamrok Ilima, Ohio MR-200, Ohio-MR-17 and Wisconsin SMR-9

★ Adromonoecious variety: White Lemon (Australian variety)

2. MUSKMELON

2. **Wholesome food/ kharbooz**: *Cucumis melo*: 2n=2X=24: Origin: Tropical Africa (Sahara Desert)

★ It have a good inter-state trade in India

★ Melon used as vegetable: Round melon and Long melon

★ Immature melons may be used fresh in salads, cooked (soup, stew, curry, stir-fry) or pickled

★ Mature fruit may be eaten fresh as a dessert fruit

★ Edible portion of melons contain water 90% and CHO 10%

★ Cantaloupe contains 45 mg and Honey Dew 32 mg of Vitamin-C per 100 g of edible portion

★ Muskmelon mixed crop with sugarcane in Uttar Pradesh

★ Variety Sarda melon is grown in Afghanistan and is available in India in October-November

★ Muskmelon seed doesnot germinate at temperature lower than 18°C

★ Muskmelon is slightly more tolerant to soil acidity

★ Predominant sex form in muskmelon: Andromonoecious

★ Hand pollination is necessary for andromonoecious types

★ Ideal for sugar accumulation: cool nights and warm weather

★ High quality melons should have TSS: 12-15% or more

★ Seed rate: 5-6 kg/ha

★ Melon is a diploid species

★ Fruit set in monoecious lines of *Cucumis melo* is 29-42%

★ Male sterile line (*ms-5*) has been used for production of commercial exploited for F_1 hybrid production

★ Ideal accumulation of sugar in the muskmelon fruits: Cool night and warm days

★ The yellow and orange-fleshed melons contain more than 350 mg of β-carotene, a precursor of vitamin A

★ 1st Horticultural classification of melons was given by Naudin (1859) and modified by Munger and Robinson (1991)

★ *C. melo* is the most variable species of the genus *Cucumis*

- **Snap melon**: *Cucumis melo* var. *momordica*: Resistant to DM, PM and CGMMV
  - Snap melon variety: Pusa Shandar
- Snap melon and musk melon are intercrossable
- **Kakri/Vellaraikkai**: *Cucumis melo* var. *utilissimus*: Used as salad
- Snakemelon (var.*flexuosus*) is important salad-type melon in north India.

- **Aromatic melon**: *Cucumis melo var. reticulatus*
- Resistance to fruit fly (*Dacus cucurbitae*): *Cucumis trigonus* (syn. *C. callosus*)
- Resistant to nematode: *Cucumis anguria, Cucumis ficifolia* and *Cucumis metuliferus* are
- Gooseberry gourd: *Cucumis myriocarbus*

★ Harvested at full slip stage
★ Long distance → Half slip stage
★ Full slip stage of muskmelon contains maximum sugar
★ Climacteric fruit

Varieties of muskmelon:

Varieties/Hybrid	Breeding methods	Remarks
IIHR Varieties:		
Arka Jeet	-	High TSS variety
Arka Rajhans	-	Tolerant to powdery mildew
IARI Varieties:		
Pusa Madhuras	-	-
Pusa Sharbati	Kutana × PMR-6 (USA)	-
Pusa Madhurima	-	-
Pusa Sarda	-	First variety of Sarda melon, suitable for net-house under north Indian plains
IIVR Varieties:		
Kashi Madhu	-	Long storage capacity
Punjab Raseela	Phoot × Indian cultivar	Moderately resistant to downy mildew
Punjab Sunehri	Hara Madhu × Edisto	-
Hisar Madhur	-	-
Hisar Saras	-	-
Hara Madhu	-	Don't slip stage at maturity
Durgapura Madhu	-	-
MHY-5	Durgapura Madhu × Hara Madhu	-
Jobner 96-2	-	-
F_1 Hybrid:		
Pusa Rasraj	M-3 × Durgapura Madhu	Utilization of monoecious line
Punjab Hybrid	MS-1 × Hara Madhu	1st F_1 hybrid
MH-10	Gynoecious line × Indian cultivar	

Specific features of important variety:

★ Non slip stage variety: Hara Madhu
★ New long melon variety: Pusa Utkarsh
★ Resistant to Fusarium wilt: Golden Gopher, Iriquois, Minnesota Midget, Harvest Queen, Delicious 51
★ Exotic varieties: PMR-45, Jacumba and Campo

Important pest and disease

- Powdery mildew: The most prevalent species is *Podosphaera xanthii*
- First variety resistant to powdery mildew: PMR 45 followed by PMR-6, 7
- Downy mildew: *Pseudoperonospora cubensis*. Major problem in temperate and tropical regions with high relative humidity.
- Fusarium wilt: *Fusarium oxysporum* f. sp. *melonis* is a soil-borne disease causing (Four races have been reported. Two resistant genes: *Fom-1*, *Fom-2*)
- Sudden wilt disease of melon: *Monosporascus cannonballus*
- Gummy stem blight: *Didymella bryoniae*-major problem in hot and humid conditions (tropical, subtropical regions and greenhouses).
- CMV, CGMMV, SqMV, PRSV, and ZYMV are prominent in the spring (dry season) crop of cucurbits

Melons	
Common name	**Botanical name**
Musk Melon	*Cucumis melo*
Long/Serpent melon/Kakri	*Cucumis melo var. utilissimus*
Oriental pickling melon	*Cucumis melo var. conomon*
Snap Melon/Phoot/Phoonte Melon	*Cucumis melo var. momordica*
Nutmeg melon/Netted melon/Persian Melon	*Cucumis melo* var. *reticulatus*
Serpent melon/Snake melon	*Cucumis melo* var. *flexuosus*
Mango melon/Garden melon	*Cucumis melo* var. *chicko*

Pomegranate melon/Queen Anne's Pocket Melon	*Cucumis melo* var. *dudaim*
Winter Melon/Honey dew	*Cucumis melo* var. *inodorus*
New melon	*Cucumis melo* var. *albida*
Lemon melon	*Cucumis melo* var. *chito*
Orange melon	*Cucumis melo* var. *hime*
Pineapple melon	*Cucumis melo* var. *saccharinus*
Cantaloupe	*Cucumis melo* var. *cantalupensis*
Weed melon	*Cucumis melo* var. *agrestis*
Sour melon	*Cucumis melo* var. *acidulus*
Egg Melon	*Cucumis melo* var. *tamago*

3. WATERMELON

3. **Food for 22nd century /Common mans fruit:** *Citrullus vulgaris or Citrullus lanatus*: 2n=2X=22: Origin: Tropical Africa

- ★ Edible portion: Endocarp (Placenta)
- ★ The watermelon fruit contains 93% water
- ★ Morphological marker: non-lobed leaves
- ★ Botanical varieties: 2

1. Citron melon/Tsamma melon: *Citrullus lanatus* var. *citroides*: Rind is used as a preservative for pickles
2. Watermelon: *Citrullus lanatus* var. *lanatus*

- ✦ Progenitor/ancestral of watermelon: *Citrullus colocynthis*
- ✦ Nodena melon: *Citrullus naudianus* (resistance to fusarium wilt and anthracnose)

- ★ All Citrullus species are cross-compatible with each other.
- ★ *C. colocynthis* are cross-compatible with water melon
- ★ Watermelon egsiseed type: Seeds are covered with fleshy pericarp
- ★ Mini watermelon fruit weight (2-4 kg) popular in India
- ★ Icebox variety fruit weight: 4-5.5 kg of fruit weight: Suitable for city peoples
- ★ Jubilee type: 8-12 kg, sugar baby type: 6-10 kg
- ★ Highly cross pollinated crop due to monoecious
- ★ Seed rate: 3-5 kg/ha
- ★ Triploid watermelon was developed by Japan Scientist Dr. Kihara (1951)

- ★ Tri-X-313 popular triploid lines widely utilized
- ★ Production of tetraploid plants: 0.2-0.4% of colchicine treatment
- ★ TIBA @ 25-250 ppm increase the fruit yield
- ★ Blossom end rot of water melon is due to high temperature, irregular of moisture supply and calcium deficiency
- ★ White heart is the physiological disorder commonly found in Indian varieties
- ★ Among cucurbit 1st hybrid developed in watermelon
- ★ The fruits stored for 2 to 3 weeks at 10 to 15°C and 90% humidity after harvest
- ★ Watermelon skin colour and flesh colour is governed by polygenes

Varieties of watermelon:

Varieties	Breeding methods	Features
Asahi Yamato	Introduced from Japan	-
Sugar Baby	Introduced from USA	-
New Hampshire Midget	Introduced form USA	Suitable variety for home garden
Improved Shipper	Introduced form USA	-
PKM-1	Selection from local type	-
RAU, Rajasthan		
Durgapura Meetha	Selection from local cultivar	-
Durgapura Kesar	Selection from local type	Yellow fleshed variety
Durgapura Lal	Sugar Baby × K-3 566	Unlobed leaf marker
IIHR Varieties:		
Arka Muthu	-	-
Arka Akash	-	-
Arka Manik	IIHR-21 × Crimson Sweet	Resistance to anthracnose and powdery mildew
F_1 Hybrid:		
Arka Jyoti	IIHR-20 × Crimson Sweet	-
Arka Madhura	Triploid seedless	Suitable for year round production under protected condition
Arka Aiswarya	-	
Arka Akash	-	
Pusa Bedana (2n=33)	Tetra-2 (4x) × Pusa Rasal (2x)	Triploid (3x) seedless watermelon

★ *Tetra-2* is a very attractive and stable tetraploid variety
★ Resistant to anthracnose variety: Congo
★ Resistant to *Fusarium* wilt: Conqueror
★ Resistant to *Fusarium* wilt and anthracnose: Fairfax

Major pest and disease

- Cucumber green mottle mosaic virus (CGMMV): Transmitted by seed and mechanical
- Gummy stem blight: fungal pathogen Didymella bryoniae. The fungus dispersed by wate splashing
- Papaya ringspot virus-Watermelon Strain (PRSV-W). The virus is transmitted by aphids (*Myzus persicae* and *Aphis* spp)
- Bacterial fruit blotch (BFB): *Acidovorax avenae* subsp. *citrulli*: Seed borne disease

4. ROUND MELON

4. **Round melon**: *Citrullus vulgaris* var. *fistulosus*: 2n=2X=24: Origin: India
★ Round melon is also known as squash melon or Indian Squash or Tinda
★ Economic part: Immature fruits
★ Round melon is useful for cough and improving blood circulation
★ Optimum temperature for germination of round melon seed is 27°C
★ MH is the most effective PGR which enhances femaleness in tinda
★ Tinda fruit is harvested at tender stage
★ **Variety**: Arka Tinda, Pusa Raunak (New variety)

5. BITTERGOURD

5. **Balsam Pear/Bitter Melon**: *Momordica charantia*: 2n=2X=22
★ Bitter gourd fruits are rich source of iron (2mg/100g)
★ 'Cheratin- cucurbitacin like alkaloids' - Antidiabetic property present in fruits
✦ Progenitor of bittergourd: *Momordica charantia* var. *abbreviata*
✦ Small fruited types: *Momordica charantia* var. *muricata*
★ Dioecious tuberous species, Perennial in nature
1) Spine gourd/Kartoli/Balsam Apple: *Momordica dioica* 2n=2X=28: Evening anthesis species

2) Sweet gourd/Kakrol/Kheksa: *Momordica cochinchinensis* 2n=2X=28: Rich in β-carotene
3) Teasle gourd: *Momordica subangolata ssp. renigera*: 2n = 56:
✦ Segmented auto polyploidy origin (Spine gourd × Sweet gourd)
4) *Momordica sahyadrica*
✦ All 4 species produce bitterless fruits
★ Monoecious and bitterfruit species: *Momordica charantia* (2n=22) and *Momordica balsamina* (2n=22)
★ Bittergourd is incompatible with *M. dioica* and *M. balsamina*
★ Optimum temperature for bittergourd cultivation is 24-27°C
★ Seed rate: 4.5-6 kg/ha
★ Seed germination enhanced by GA_3 @ 25-50 ppm
★ For enhancing the female: male ration: MH @ 50-150 ppm and CCC @ 50-100 ppm
★ For induction of hermaphrodite flower: $AgNo_3$ @ 400 ppm at pre-flowering stage
★ Heterosis in bittergourd was 1st studied by Pal and Singh (1946)
★ Gynoecious in bittergourd is controlled by single recessive gene (*Gy1*)
★ Bittergourd gynoecious lines: *DBGy- 201* and *DBGy- 202*
★ In South India, bitter gourd is trained on bower system
★ Seed protein (*ricine*) of bittergourd inhibited growth of immuno virus (HIV) in human cell culture
★ *Bitter gourd:* Inheritance of fruit colour and surface are Monogenic. Green, Spiny fruits being Dominant over White and smooth fruits respectively (Vahab, 1989)

Varieties of bittergourd:

Varieties	Breeding methods	Remarks
Pusa Aushadhi		New variety
Pusa Purvi		Small Bittergourd variety
Pusa Rasdar		Su… …ed struct…
Pusa Do Mausami	-	S… …y
Pusa Vishesh		
Arka Harit		
Arka Anupama		
Pant Karela		

Priyanka	-	White colour variety
Preethi	-	White colour variety
Konkan Tara	-	Long shelf life and export variety
VK-1(Priya)	-	-
Kashi Urvasi	IC-85650B × IC-44435A	-
Phule Green Gold	Green Long × Delhi Local	Tolerant to downy mildew
MDU-1	**Mutant variety**	-
CBM-12	*Momordica charantia* var. *muricata*	Anti-diabetic variety
F_1 hybrid:		
Pusa Hybrid-1	Pusa Do Mausami × Pusa Vishesh	Suitable for growing in spring- summer season
Pusa Hybrid-2	S-63 × Pusa Do Mausami	-
COBgoH 1	-	-

6. BOTTLEGOURD

6. **Bottlegourd/ White Flowered Gourd**: *Lagenaria* siceraria: 2n=2X=22: Origin: Africa and India
   - ★ Shallow rooted crop
   - ★ Prefers a hot and humid climate for the best growth
   - ★ It withstand cold climate better than muskmelon and watermelon
   - ★ Short day and humid climate produce female flowers
   - ★ Bower system of training practised in Maharashtra
   - ★ Optimum temperature for seed germination: 25-30°C
   - ★ Cross pollinated crop
   - ★ Female: Male ration: 2:1 or 3:1
   - ★ Pinching of male flowers on female plant is commercially practised for hybrid seed production
   - ★ MH @ 400 ppm promotes the female flower production and increases fruit set
   - ★ Increase fruit set: Ethrel 100-150 ppm, MH 400 ppm, TIBA 50 ppm
   - ★ Seed rate: 6-8 kg/ha

Varieties of bottlegourd:

Varieties	Breeding methods	Special features
IARI Variety:		
Pusa Summer Prolific Long (PSPL)	-	Suitable for both summer and *kharif* seasons
Pusa Summer Prolific Round (PSPR)	-	Suitable for both summer and *kharif* seasons
Pusa Sandesh	-	-
Pusa Samridhi	Non-crook neck variety	-
Pusa Santushti	Pear shaped fruits	Suitable for throughout the year, Hot and cold set variety
Pusa Naveen	Non-crook neck variety	Suitable for packing for long distance transportation
Arka Bahar	Non-crook neck variety	Variety suitable for export
Samrat	-	-
Pant Sankar Lauki 1	-	-
IIVR Varieties:		
Kashi Bahar	-	Long fruited hybrid
Kashi Ganga	IC-92465 × DVBG-151	Early variety
F_1 Hybrid:		
Pusa Meghdoot	PSPL × Sel.2	Suitable for summer and rainy seasons
Pusa Manjari	PSPR × Sel.11	Suitable for summer and rainy seasons
Pusa Hybrid-3	Pusa Naveen × Sel P-8	Suitable for easy packing and long distance transportation
CO (Bgo)H-1	-	-

7. SNAKE GOURD

7. **Cucumber of the southern barbarians**: *Trichosanthes cucumerina*: 2n=2X=24: Origin: India
   - ★ Snake gourd occupies a pride of place among vegetables in South India
   - ★ 'Trichosanthinn' compound used for anti-HIV activity

- *Trichosanthes* is the largest genus in the cucurbitaceae family
  - Progenitor of snakegourd: *Trichosanthes lobata*
  - Japans Snakegourd : *Trichosanthes origera*
  - Chinese snake gourd: *Trichosanthes kirilowii*
- Flower colour: White
- Tendrillar flower common in snakegourd
- Commonly followed training system: Bower or arbour system
- **Varieties**: Konkan Sweta- Suitable for cultivation in both kharif and hot weather seasons, CO-1, CO-2 (Short fruited variety), PKM-1 (Long fruited variety)

8. POINTED GOURD

8. **King of gourds/Parwal**: *Trichosanthes dioica*: 2n=2X=24: Origin: India
- Dioecious, perennial climbing or trailing habit
- Primary centre of origin: Bengal-Assam Area
- Parwal is good crop for riverbed cultivation
- *Salicylic acid* enhanced postharvest life of fruits
- **IIVR Variety**: Kashi Alankar
- Commercial propagation by stem cuttings
- Cuttings requirement: 2000-2500 cuttings/ha

9. ASH GOURD

9. **Wax gourd /Hairy Melon/Winter Melon/, Ash Pumpkin/White Pumpkin/Chinese Preserving Melon/Wax Gourd/White Gourd/Petha**: *Benincasa hispida*: 2n=2X=24: Origin: Japan and Java
- Monoecious annual climber
- Ash gourd is good for people suffering from weak nervous system (nervousness) and debility
- The ayurvedic "Kooshmanda Asayan" is prepared from Ash Gourd
- *Agra Petha* is a famous sweet prepared from ash gourd
- Optimum temperature requirement for cultivation is 24-30°C
- Seed rate: 5-7 kg/ha
- **Varieties:**
  - Pusa Ujjwal: Ideal variety for petha preparation
  - New varieties: Pusa Urmi, Pusa Shreyali, Pusa Sabzipetha
  - Mudliar is a variety of ashgourd

- **IIVR varieties**:
  - Kashi Dhawal: Suitable for *petha*
  - Kashi Ujwal: Suitable for candy/petha
  - Kashi Surbhi: Distant hybrid

10. LITTLE GOURD

10. **Kundru /Tondali/Ivy gourd**: *Coccinia indica*: Cucurbitaceae: Edible parts: Immature fruits
- Dioecious crop
- More sensitive to water logging
- All the plant parts of coccinia are useful for preparation against cure of bronchitis and diabetes
- Commercial propagation by cutting
- Planting time: June-July and February-March
- **Varieties: KAU:** Sulabha, IGKY, **Raipur, Chhattisgarh**: Indira kundru-05, Indira kundru-35

11. SPONGE GOURD

11. **Sponge gourd** (*Luffa acutangula*) 2n=2X=26 and **ridge gourd** (*Luffa cylindrica*) 2n=2X=26: Origin: India
- Gelatinous compound present in Luffa is called as "*Luffein*"
- Rainy season vegetable
- Flower colour of sponge gourd: Deep Yellow
- Flower colour of ridge gourd: Pale yellow
- Ridge gourd anthesis time: Evening hours
- Sponge gourd anthesis time: Morning hours
- Sponge gourd fruits contain higher protein and carotene than ridge gourd
  - Progenitor of cultivated smooth and ridge gourd species: *Luffa graveolens*
  - All species of *Luffa* species are monoecious, except *Luffa echinata* which is dioecious
- The trend of evoluation in *Luffa* as given by Dutt and Roy (1971)
- Seed rate: 4-5 kg/ha

Varieties of ridge gourd and sponge gourd:

Ridge gourd	Sponge gourd
Pusa Nutan	Pusa Chikni
Pusa Nasdar	Pusa Supriya
Arka Sumeet	Pusa Sneha
Arka Sujath	GFE SMG-108
PKM-1- Induced mutant	Phule Prajakta
CO-1 and CO-2	Kashi Divya
Punjab Sadabahar	
Satputia- Hermaphrodite variety	
Konkan Harita	

12. PUMPKIN AND SQUASHES

12. **Pumpkin and Squashes**: 2n=2X=40: Origin: Tropical America

- ★ Pumpkin festival celebrated in USA
- ★ Genomic structure of pumpkin *Cucurbita moschata* is AABB: Amphidiploid
- ★ The cultivated (domesticated) species of the genus *Cucurbita is* five
- ★ Summer squash: *C. pepo* (economic part: immature fruits, origin: North America)
- ★ Xerophytic forms: *C. digitata, C. palmata, C. clindiata, C. foetidissima*
- ★ Mesophytic forms: *C. ficifolia, C. sororia, C. lundelliana*
- ★ Pumpkin vitamin-A: 1600 IU
- ★ Commonly grown species in India: *Cucurbita moschata*
- ★ Popular summer squash group: Zucchini
- ★ Summer squash/Bushy gourd: Origin: North Eastern Mexico: Edible portion: immature fruits
- ★ Largest pumpkin fruits bears summer squash species
- ★ *Cucurbita maxima* is grown mostly on the hills
  - ✦ Progenitor of summer squash: *Cucurbita fratena*
  - ✦ Fig leaf gourd or Malabar gourd: *Cucurbita ficifolia*
  - ✦ Buffalo gourd: *Cucurbita foetidissima*: Development of gynoecious line and resistant to viruses
  - ✦ Peten gourd: *Cucurbita lundelliana*: Resistant to powdery mildew
- ★ Pumpkin is highly cross pollinated-entomophily due to monoecious nature
- ★ No inbreeding depression in pumpkin

- ★ Flower of pumpkin have more nutritive value than fruits
- ★ Optimum temperature for pumpkin cultivation is 18-24°C
- ★ Pumpkins: Resistance to fruit fly is governed by single dominant gene (F)
- ★ Ethephon @ 600 ppm: commercially utilised for hybrid seed production in summer squash

Cucurbita groups	Specific features
1. Pumpkin	
Arka Chandan	Highest β-carotene variety (3331 IU/100g)
Pusa Vikas	Rich source of beta carotene
Pusa Vishwas, CM-14, Pusa Hybrid-1	
2. Summer Squash	
Patty Pan, Australian Green, Early Yellow Prolific	Introduced from USA
Punjab Chappan Kaddu-1, Kashi Harit	
Pusa Pasand	Round fruited type
F_1 Hybrid: Pusa Alankar: EC-27050 ×Sel.IPI-8	
3. Winter Squash	
Arka Suryamukhi	Resistant to fruit fly
Transgenic variety: Freedom: Resistant to *Zucchini* virus	

13. CHOW-CHOW

13. **Chow-chow**: *Sechium edule*: Origin: Southern Mexico

- ★ Herbaceous perennial climbing monoecious vine with large tuberous roots
- ★ Only single seeded fruit member of cucurbitaceae family
- ★ Among gourds richest in nutritive value in carbhohydrate (6.3%) and calorific value
- ★ Viviparous germination habit
- ★ Fruits as well as tuberous roots of chow-chow are used as vegetables
- ★ Highly sensitive to frost
- ★ Edible part: Fruit and tuberous roots
- ★ Commercially propagated by sprouted fruits
- ★ Storage life: 2-4 weeks under normal condition
- ★ Types: Round White, Long White, Pointed Green, Broad Green and Creamy Green
- ★ Major fruit bearing season: October-November
- ★ Yield: 500-600 q/ha

Disease and pest of cucurbits:

Diseases	Casual organism	Vector	Affected crop
Powdery mildew	*Erysiphe cichoracearum*	-	All cucurbits
Downy mildew	*Pseudoperanospora cubensis*	-	All cucurbits
Witches broom	MLOs	Leaf hoppers	Mostly in Bittergourd
Green mottle mosaic	Virus	Seeds	Mostly in cucumber
Bud necrosis	Virus	Seeds	Mostly in watermelon
Pests			
Fruit fly	*Daucus cucurbitae*		Affect the young plants
Red pumpkin beetle	*Aulacophora foveicollis*		Affect the cotylendonary leaf stage

F. Leguminous Vegetable Crops

1. **Garden Pea**
2. **French Bean**
3. **Indian Bean**
4. **Cluster Bean**
5. **Cowpea**
6. **Broad Bean**
7. **Winged Bean**
8. **Leguminous Tuber Crops**
9. **Minor Leguminous Vegetable Crop**

- Central Asia was regarded as the birth place of all legumes
- Legume vegetables belongs to family: Fabaceae
- **Major leguminous vegetable crops:** Garden Pea, Indian Bean, Cowpea, French bean, Lima bean
- **Minor leguminous vegetable crops:** Gotani Bean, Sword Bean, Jack Bean, Soybean , Yam Bean

1. GARDEN PEA

1. **Garden Pea**: *Pisum sativum*: 2n=2X=14: Family: Fabaceae Origin: Central Asia
   - Pea is a herbaceous winter annual
   - Pea is one of the world's oldest domesticated crops
     - Ancestor of pea or Mediterranean Pea: *Pisum elatius*
     - Field pea : *Pisum sativum* var. *arvense*
     - **Garden pea/Horticultural Pea/Sweet pea:** ***Pisum sativum* var. *hortense***
     - Edible podded variety: *Pisum sativum var. macrocarpum*
     - Dwarf Pea: *Pisum humile*
     - Red Yellow Pea: *Pisum fulvum*
     - Abyssinicum Pea: *Pisum abyssinicum*
   - Garden pea is a choice vegetable grown for its fresh shelled green seeds
   - The green shelled seeds rich in protein (7.2 %), vitamins and minerals
   - Green seeds are used as vegetable or can be used after processing (canning, freezing and dehydration)
   - Garden pea is a cool season crop mainly grown during winter season in plains and during summer season in hills.
   - Edible podded peas are 2 types:
     - Snap pea (*Pisum sativum* var. *macrocarpon*): Lack of parchment layer, thick pod walls

- Snow peas or china pea (*Pisum sativum* var. *saccharatum*): Lack of parchment layer, thin pod walls
- Most important garden pea growing state: Uttar Pradesh (46.1%)
- Leading pea producing states: UP > MP > Jharkhand
- Highest Productivity: Jammu & Kashmir
- Protein content:
  - Smooth seed: 23-31%
  - Wrinkle seed: 33%
- Whole pod edible pea also known as snap pea or sugar snap pea: the pods are devoid of fibrous parchment layer
- Lack of parchment layer trait (fiberlessness) in pod wall is controlled by a single recessive gene *sin-2*.
- Edible podded peas originated from spontaneous mutation
- World famous Garden pea breeder: S. Blixt (Father of pea breeding)
- Pea germplasm is maintained at Nordic Gene Bank, Lund, Sweden
- Round seeded varieties are more tolerant to higher temperature than wrinkle seeded
- Pea is a self-pollinated crop due to presence of cleistogamous flowers
- Optimum temperature for pea seed germination about 22°C

Seasons:

- Early season: varieties are dwarf, pod maturity: 40 to 45 days, total duration: 60- 70 days: better price in market
- Mid season varieties: pod maturity in 60 to 65 days, total duration: 90 days
- Late varieties: Tall (4 to 5ft) and needs staking. Pod maturity: 90 days and total duration: 120 days
- Seed rate:
  - Early: 100-120 kg/ha
  - Mid-late: 80-90 kg/ha
- Seed yield: 1500-2000 kg/ha
- Viability of garden pea: 2-3 years
- Shelling percentage of pea: 35-45%
- Sowing time in North Indian Plains: October-Mid November
- Pod maturity of garden pea is determined by tendrometer
- Pea aphid is a serious pest causing curling of leaves and pods
- Bacterial wilt and powdery mildew (*er-1, er-2*) of pea are governed by single recessive gene

- Afila: Snoad, 1974. Introduced the *st* gene (reduced stipule size) and the *af* (afila) gene where leaflets get converted into branched tendrils. Plant with the genetic constitution *af af* and *st st* are called "leafless".
- Leafless pea (*afila*) is tolerant to waterlogging and suitable for mechanical harvesting
- Acacia: The tendrils are converted into leaflets
- Heat unit system: commonly used for determine the maturity of pods
- Eleiofil: The leaflets are subdivided repeatedly and multiple leaflets confuse the plants to be of peas
- Average heat units time for pea: 4.4°C
- Application of chloromequat induce the drought tolerance in peas: Foliar application: 3-6 kg/ha and Soil application: 6 kg/ha

Early Varieties:

Early Group	
Ageta	Fusarium wilt resistant, (PAU)
Alaska, Early superb, Little Marvel, Meteor	Introduced from England
Arkel	Introduction from England, IARI
AP-3	Kalyanpur
Asauiji	IARI
Early Badger	Introduced form USA -
Kashi Kanak, Kashi Nandini, Kashi Udai	IIVR
VL-7	VPKAS, Almora

Mid Varieties:

Mid-season	
Bonneville	Introduced form USA (IARI)
Alderman	Introduced form USA, Suitable for freezing
Sylvia	Introduced from Sweden Whole pod edibl (IARI)
Arka Ajit, Arka Karthik, Arka Priya Arka Pramodh, Arka Sampoorna	Resistant to powdery milde
Lincoln	Introduced form USA
Kashi Shakti, Kashi Samridhi	IIVR
Punjab 88	

Specific features of important variety:

- ★ All over India grown varieties: Bonneville, Arkel, Pusa Pragati
- ★ Whole pod (snap pod) edible group: Arka Sampoorna, Arka Apoorva, Oregon sugar pod, Swarna Tripti
- ★ New variety: Pusa Shree
- ★ Snap Pea varieties: Sugar stick, Sugar Snap, Sugar Bon, Sugar Lady
- ★ Suitable for both fresh market and dehydration variety: Arkel
- ★ Suitable for dehydration: Arkel (Wrinkled and dark green seeds)
- ★ Smooth seeded variety: Asauiji and Meteor
- ★ Wrinkle seeded variety: Arkel and Bonneville
- ★ Good caning variety; Fusarium wilt resistant variety: Early Badger (wrinkled seeded)
- ★ JNKVV, Jabalpur Early varieties: Jawahar Matar 3, 4, Harbhajan
- ★ Resistant powdery mildew: JP 83
- ★ Mithi Phali: Edible podded
- ★ JP-19: Edible podded, Resistant to powdery mildew
- ★ Pusa Pragati: Resistant to powdery mildew
- ★ Early maturing powdery mildew resistant variety: Kashi Mukti
- ★ Resistant to powdery mildew: Palam Priya
- ★ Most popular variety of Madhya Pradesh: Khaper Kheda
- ★ Edible podded (pods soft without any parchment layer) variety of garden pea: Sylvia
- ★ Fusarium wilt resistant variety: Alaska, Surprise
- ★ Resistant source of pea aphid Feltham First and Meteor
- ★ Tolerant to salinity New Line Perfection, Market Prize and Duke of Albany
- ★ Branching habit pea variety: Lincoln and Wando
- ★ Late varieties highly susceptible to powdery mildew
- ★ Early varieties susceptible to fusarium wilt
- ★ Fusarium wilt most devastating diseases of pea, yield losses up to 93% in India

Diseases of garden pea:

Diseases	Casual organism	Features/inheritance
Root rots	*Aphanomyces euteiches*	most destructive pea diseases in worldwide
Powdery mildew	*Erysiphe polygoni*	Single recessive gene (*er-1, er-2*)
Ascochyta foot rot	*Ascochyta pisi*	Single dominant gene and duplicate gene
Fusarium Wilt	*Fusarium oxysporium* pv. *pisi*	Single dominant gene (*Fw*)
Rust	*Uromyces pisi*	Single dominant gene
Near wilt	*Fusarium oxysporium* pv. *pisi* (race-2)	Single dominant gene (*Fnw*)

2. FRENCH BEAN

2. **French bean:** *Phaseolus vulgaris*: 2n=2X=22: Origin: South Mexico and Central America

- ★ **Syn:** Kidney Bean, Haricot Bean, Snap Bean, Navy Bean, Common Bean
- ★ Crop of temperate regions
- ★ Sunday special vegetable
- ★ Used as a dry seeds and immature tender pods
- ★ Protein content: Dry seeds 17.5-28.7 %, green pods: 1-2.5 %
- ★ Shallow rooted crop
- ★ Optimum mean temperature for growth and yield of French bean: 20-25°C
- ★ Kidney bean is sensitive both to frost and to very high temperature
- ★ It is more prone to frost than other winter pulse crops.
- ★ French bean is also known as kidney bean or haricot bean or snap navy bean
- ★ Trend of french bean cultivation in india changing from bush type to pole type beans because of their long yielding period and high yield
- ★ It does not nodulate with native rhizobia or commercially produced cultures
- ★ Sowing time: Plains: September-October, Hills: April-June
- ★ Inflorescence: Raceme
- ★ Pedigree method has been the most common breeding procedure used for improvement in french bean
- ★ Pod colour is controlled by a single recessive gene: *y*
- ★ Pod straightness is important trait in processing purpose
- ★ White seed is preferred by breeders controlled by recessive gene: *p*
  - ✦ Progenitor/ancestor of French Bean: *Phaseolus aborigineus*
  - ✦ Lima Bean: *Phaseolus lunatus*
  - ✦ Scarlet Runner Bean/ Runner Bean: *Phaseolus coccineus*-cross pollinated vegetable crop
  - ✦ Tepary bean/Moth bean: *Phaseolus acutifolius* var. *latifolius*
  - ✦ Potato bean – *Pachyrrhizus tuberosus*: Tuber used as vegetable
  - ✦ Thicket Bean: *Phaseolus polystachyus*
  - ✦ Year Bean: *Phaseolus polyanthus*
  - ✦ Adzuki Bean: *Phaseolus angularis*
  - ✦ Cold tolerance species: *P. filiformis* and *P. angustissimus*
  - ✦ Salinity tolerance species: *P. filiformis*
  - ✦ Drought stress-tolerant species: *P. acutifolius*

- Seed rate:
  - Bush type: 65 kg/ha
  - Pole type: 25-30 kg/ha
- Pre-emergence herbicide application:: Flucholralin 2 lit/ha

Pest and diseases

- Rust: *Uromyces phaseoli*: epidemic disease in India
- Common bean mosaic is most serious virus disease and transmitted by *Aphids*
- Ashy stem blight is caused by fungal (*Macrophomina phaseoli*)- Seed borne disease
- Common blight is bacterial disease *Xanthomonas phaseoli*- seed borne
- Bean common mosaic (BCM) is a major problem: seed borne

Physiological disorders

- Transverse cotyledon cracking (TCC) is a major physiological disorder in French bean
- Hypocotyl cracking or necrosis is the germination disorder of French bean
- Hypocotyl cracking or necrosis disorder is due to low calcium content in seed
- Low protein in French bean is due to calcium and magnesium deficiency

Varieties of French bean:

Bush types		Pole types	
Pusa Parvati	X-ray mutant of Wax Pod	Kentucky Wonder	Introduced from USA
Arka Komal	Introduced from Australia	Pusa Himalata	
Arka Suvidha	Photoinsensitive, Resistance to rust	TKD-1	
Arka Komal	Photoinsensitive	SVM-1	Contender × PBL257
Arka Anoop	Photoinsensitive, Resistance to bacterial wilt and rust	Lakshmi	Contender × Local pole
Arka Sharath	Photoinsensitive	-	
Arka Bold	Photoinsensitive, Flat type, Resistance to bacterial wilt		
Kashi Param	-		
Phule Suyash	-		
Pant Anupama	Resistance to angular leaf spot		
Contender	Introduced from USA		

Premier	Introduced from Sweden		
Bountiful	Introduced from USA		
Jampa	Introduced from Mexico		
Giant Stringless	Introduced from Sweden		
Jampa	Resistant to wilt		
Other varieties: Kashi Param, TKD-1, YCD-1, Azad Rjmesh			

Specific features of important variety:

- Resistant to anthracnose variety: Tweed Wonder
- Popular pole bean varieties: NZ, NZ Super King, US-2 and HAPB-4
- Tender Crop and Cascade are cultivars of French bean suitable for processing
- Pusa Parvati is resistant to mosaic and powdery mildew
- Among pole types, Kentucky Wonder is most commonly grown varieties in India
- Most of the French bean varieties are day neutral
- White seed varieties pods have more sugar content
- Fusarium wilt is caused by the fungus *Fusarium oxysporum* f. sp. *Phaseoli*
- Bean Anthracnose is caused by the ascomycete fungus *Glomerella lindemuthiana*
- White mold: *Sclerotinia sclerotiorum*
- Bean Rust is caused fungus *Uromyces appendiculatus*

3. INDIAN BEAN

3. **Lab-lab:** *Lablab purpureus*: 2n=2X=22, 24: Origin: India

- Syn: Bonavist or lobia bean, Egyptian bean, Australian pea, Indian butter bean, salad bean
- Hyacinth bean is richer than French bean in nutritive value
- Perennial plant but cultivated as annual or biennial crop and suitable for rainfed condition
- Indian bean is a cool season and drought tolerant crop
- Generally pole types is photosensitive in nature
- Garden type/Vegetable type: Dolichos bean: *Dolichos lablab var. typcius*
- Field type/Pulse type: Dolichos bean: *Dolichos lablab var. lignosus*
- Methionine is the most limiting amino acid in Indian bean
- Self-pollinated crop
- Seed rate: 20-30 kg/ha
- Rewa variety have high protein content: 25.11%

Varieties of Indian bean:

Pole types	Bush types
Pusa Early Prolific, Pusa Sem-2, Pusa Sem-3	Arka Jay
Arka Sambhram	Arka Vijay
Arka Soumya	Konkan Bhusan
Arka Komal	CO-8
Arka Bold	**Mutant variety:** CO-9, CO-10
Arka Amogh	CO-9: Spontaneous mutant MS-98678
Kashi Harittima	CO-10: X ray induced mutant of CO-6
Rajni, KDB-403, KDB-405	CO-11
Dasarawal	CO-12
Deepaliwal	
JDL-79, JDL-53	
CO-1: Selection from *HD-18* of Hisar	
CO-2-Selection from *Chinna Avarai*	
CO-3- Selection from *Yanaikathu Avarai*	
CO-4: Selection from *Sivappu Avarai*	
CO-5: Selection from *Kozhikkal Avarai*	

- ★ Suitable for dual purpose: Arka Vijay and Konkan Bhusan
- ★ Bush type, pods are not edible -Most useful for incorporating dwarf plant characteristics in hybridization programme: Hebbal Avare
- ★ Bush type, photoinsensitive, tolerant to heat and drought: Arka Jay and Arka Vijay
- ★ Suitable for vegetable purpose: Arka Jay

Disease of common bean:

Diseases	Casual organism	Vectors
Anthracnose	*Colletotrichum lindemuthianum*	
Web blight	*Rhizoctonia solani*	
Angular leaf spot	*Pseudocercospora griseola*	
Floury leaf spot	*Mycovellosiella phaseoli*	
Yellow flecks	MLOs	White fly
Phyllody	MLOs	Leaf hoppers
Golden mosaic	Virus	White fly
Yellow mosaic	Virus	White fly

4. CLUSTER BEAN

4. **Guar/Cluster bean:** *Cyamopsis tetragonolobus*: 2n=2X=14: Origin: West Africa and India
   - ★ Gum used in textile, paper, cosmetic and oil industries
   - ★ Largest growing state: Rajasthan (82%)
   - ★ Warm season crop, short day plant
   - ★ Androecium is monodelphous
   - ★ Self-pollinated crop
   - ★ Tolerant to drought
     - ✦ Ancestor of Guar: *Cyamopsis senegalensis*
   - ★ Cluster bean contains a mucilaginous substance in seed is known as "galactomannan"
   - ★ The Guar meal (dry seeds) contains about 33.3% protein
   - ★ Cluster bean seeds contain 68-70% galactomannan polysaccharides, also known as Guar gum
   - ★ Gum of cluster bean composed of D-galactopyranose and D-mannopyranose units
   - ★ Young plants of cluster bean contain hydrocyanic acid which cause toxicity to animals
   - ★ Harvesting of cluster bean for forage purpose should be done from flowering to fruiting stage
   - ★ Bacterial wilt (*Xanthomonas cyamopsidicola*) is the most serious disease of cluster bean
   - ★ Seed rate: 30-40 kg/ha

Varieties of cluster bean:

Varieties	Breeding methods	Special features
Goma Manjari	-	Resistant to Powdery mildew, Bacterial blight and Leaf spot
Pusa Mausami	Suitable for rainy season	Densely branching
Pusa Sadabahar	Suitable for summer and rainy season	Single stem, Non branching, National variety, Popular in India
Pusa Navbahar	Pusa Mausami × Pusa Sadabahar	Single stem variety of cluster bean

5. COWPEA

5. **Asparagus bean/yard long bean:** *Vigna unguiculata:* 2n=2X=22: Origi... ...ca
   - ★ Cowpea syn: China Pea, Black eyed pea, Kathir Pea, Sothern Be...
   - ★ Vegetable cowpea: Immature pods used as vegetable
   - ★ Day neutral plant
   - ★ Shallow rooted vegetable crop

- ★ Rainy season vegetable
- ★ Suitable for sequential and intercropping system
- ★ Flowers are borne in multiple raceme
- ★ Self-pollinated crop
  - ✦ Ancestor of cowpea: *Vigna unguilata* var. *mensensii*
  - ✦ Yard long bean/Snake bean/Asparagus bean/String: *Vigna sinensis* var. *sesquipedalis* Used as vegetables
  - ✦ Catjang bean: *Vigna sinensis* var. *cylindrica*
  - ✦ Long penducles Cowpea/ Fibre cowpea: *Vigna unguigulata* cv.gr.*textilis*
  - ✦ Pulse type: *Vigna unguigulata* var. *radiata*
  - ✦ Dual-purpose: *Vigna unguigulata* var. *cylinidrca*
- ★ Resistant to pod borer: *Vigna unguigulata* cv. gr. *biflora*
- ★ Most common method of breeding: Pedigree method
- ★ International cowpea breeding work is carried out International Institute of Tropical Agriculture, Ibadan, Nigeria
- ★ Protein content in cowpea seeds varies 23-28%
- ★ Kashi Kanchan: popular among the farmers

Varieties of cowpea:

Varieties	Breeding methods	Special features
Pusa Phalguni	Introduced from Philippines	Spring season
Pusa Barsati	Introduced from Philippines	Rainy season
Pusa Dofasli	Pusa Phalguni × Philippines selection	Both seasons
Pusa Komal	-	Suitable for both summer and rainy, Bacterial blight resistant variety
Pusa Sukomal	-	Highly resistant to golden yellow mosaic virus and leaf spot disease
Pusa Rituraj	-	Dual purpose
Konkan Wali	-	Yard Long Bean variety
Arka Garima	Bushy type	Photoinsensitive
Arka Suman	Bushy type	Photoinsensitve, Resistant to rust
Arka Samrudhi	Bushy type	Photoinsensitive
Arka Mangala	-	Photo insensitive, Recent variety
Kashi Shymal	-	Tolerant to golden mosaic virus
Kashi Sudha Kashi Kashi Gauri Kanchan Kashi Unnati	Bushy type, Photoinsensitive	Resistant to golden mosaic virus and *Cercospora* leaf spot

6. BROAD BEAN

6. **Broad bean**: *Vicia faba*: 2n=2X=12, 14: Origin: Europe and Asia
   - ★ Broad Bean is also known as "Faba Bean, Horse Bean, Bakla Bean"
   - ★ Illness to human is caused due to allergy of pollen and green pod of Broad Bean which is known as Favism
   - ★ Dancing style of stigma present in broad bean
   - ★ All beans are susceptible to frost except Broad Bean
   - ★ Seed rate: 70-100 kg/ha
   - ★ **Varieties**: Pusa Sumeet, Pusa Udit

7. WINGED BEAN

7. **God sent vegetable/Winged bean/Goa bean**: *Psophocarpus tetragonolobus*: 2n=2X=18 or 22 Origin: Madagascar
   - ★ Syn: Asparagus pea/Princess Pea/Soyal Rival/ Vegetable of 20th century/Super market on a stalk/Four angled bean
   - ★ Herbaceous plant
   - ★ Practically all parts of the plants edible
   - ★ Short day plant
   - ★ Tuber contains 12-15% protein

8. LEGUMINOUS TUBER CROPS

8. **Leguminous tuber crops**: Origin: Mexico and Central America
   Yam bean/Jicama: *Pachyrrhizus erosus*: **Variety**: Rajendra Mishri Kant
   - ★ Yam bean seed oil percentage from 20-28%
   - ★ Short day plant
   - ★ Commercial propagation: Seeds
   - ★ Flower pruning is done in *Pachyrrhizus* for symbioti
   - ★ **Related species:**

- Jacatube bean: *Pachyrrhizus tuberosus*
- Andean yam bean: *Pachyrrhizus ahipa*

9. **Other minor leguminous vegetable crop species:**

Common name	Scientific name
Gotani Bean	*Canvalia plagosperma*
Sword Bean	*Canavalia gladiata*
Jack Bean	*Canavalia ensiformis*
Soybean	*Glycine max*
Yam Bean	*Pachyrrhizus erosus*
African Yam Bean	*Sphentylis stenocarpa*
Velvet Bean	*Mucuma deeringiana*

G. Bulb Vegetable Crops

1. Onion
2. Leek
3. Garlic

1. ONION

1. **Onion:** *Allium cepa*: Alliaceae: 2n=2X=16: Origin: Central Asia
   - ★ Allium is *Greek* word
   - ★ Onion belongs to monocotyledon family
   - ★ Cool season crop
   - ★ Shallow rooted crop
   - ★ It is used for against sun stroke
   - ★ Edible portion of onion is modified stem is known as bulb
   - ★ Optimum temperature for onion bulb development: 15.5-21°C
   - ★ Optimum temperature for onion seed germination:20-25°C
   - ★ Temperature is important for seed production
   - ★ Day length is important for bulb production
   - ★ Bolting means seed stalks initiation and development
   - ★ Onion cultivars grown in plains of India are short day (10-12 hours for bulb formation), kharif (14 hours for bulb formation)
   - ★ Pungency in onion is due to allylpropyl disulfide
   - ★ Yellow colour of the outer skin of onion bulb is due to quercetin
   - ★ Anti-fungal factor in onion is phenolics compound known as catechol
   - ★ Tear inducing action of onion: Lachrymator factor: 1-Propenyl sulfonic acid
   - ★ Onion carbhohydrate: Fructan
   - ★ Bulb richest source of vanadium
   - ★ Onion contains an enzyme is called 'Allinase'
   - ★ Leading producer of onion in the world: China
   - ★ India is the 2nd largest producer of onion in the world
   - ★ India: Area 12.0 lakh ha and Production: 194 lakh tonnes, with a pro... t/ha.
   - ★ National productivity: 21.20 t/ha
   - ★ Netherland (21%) is the leading exporter o...

- Leading state in onion area and production: Maharashtra
- Leading onion producing states: Maharashtra > MP > Karnataka
- Leading onion producing countries in world: China > India (22.6%) > USA
- Lassalgoan in Maharashtra is the biggest onion market in India
- Onion accounts 77% of the total foreign exchange among fresh vegetables
- Highest productivity of onion in India: Gujarat (25.40 t/ha)
- National Research Centre for Onion and Garlic (NRCOG) is located at Nasik, Maharashtra
- NRCOG established in 1994
- New name of NRCOG, Project Directorate on Onion and Garlic (PDOG), Rajagurunagar, Maharashtra: 2008
- National Horticultural Research Development Foundation (NHRDF), Nasik, Maharashtra
- Nick name Mr. Onion given to Dr. H. A. Jones
  - Ancestor of onion: *Allium vavilovii*
  - Potato Onion/Underground Onion/Multiplier/Egyptian onion: *Allium cepa var aggregatum*
  - Leek/Great Headed Garlic/Kurrat: *Allium ampeloprasm var. porrum*
  - Kurrat: *Allium kurrat*
  - Ancestor of leek and kurrat: *Allium ampeloprasm*
  - Tree onion/Top Onion/Egyptian Tree Onion: *Allium cepa var. viviparum/proliferum*
  - Cibol (Ciboule)/Japanes Bunching Onion/Welsh Onion: *Allium fistulosum*
  - Goodding's onion: *Allium gooddingii*
  - Shallot/Perennial Onion: *Allium cepa var. ascalonicum*
  - Pink onion: *Allium cernum*
  - Chive: *Allium schoenoprasam*
  - Chinese Chive: *Allium tuberosum*
  - Asatsuki: *Allium ledebourianum*
  - Rakkyo: *Allium chinensis*
  - French Sevat: *Allium nipponicum*
  - Ramsons/Wild Garlic: *Allium ursinum*
  - *Allium roylei*: Resistant to downy mildew and leaf blight
  - *Allium victorialis*: Novel source of flavonoids (Quercetin, Kaemferol)
  - New *Allium* vegetable is commercially grown in North Korea (*Allium komarovianum*)
  - Recurrent apomixis: *Allium spp.*,
  - New source male sterile: *Allium galanthum*

- Pran (*Allium* × *cornutum*) is triploid (2n=3X=24) Octotriploid (AAB): *Allium cepa* × *Allium fistulosum*
- Generally red onion is more pungent than white onion
- Flower colour: white or bluish
- Highly cross pollinated due to protandry
- Onion is pollinated chiefly by honey bees and blow flies (excellent pollinator)
- Cytoplasmic genetic male sterility was 1st found in onion
- Most widely used source of CMS: 'S' cytoplasm
- Hybrid onion programme originated in 1925
- Selfing and massing breeding technique was developed by Jones and Mann (1963)
- 1st CMS identified in Italian Red by Dr. H. A. Jones, University of California, Davis, USA
- In onion male sterile line have been isolated in Pusa Red at IARI, New Delhi
- Common onion is commercially propagated by seed
- Seed rate:
  - Rabi : 10-12 kg/ha
  - Kharif: 12-15 kg/ha
- Onion seed viability: 1 year
- Egyptian or tree onions produce top sets or bulbils
- Required bulbs:1000-1200 kg/ha
- Best planting density for onion cultivation: 15cm × 8-10cm
- Premature harvest form a thick neck bulb
- Onion heat tolerant due to cylindrical leaf shape
- Optimum temperature for floral initiation: 10-12°C
- Flower induction: GA_3 @ 300 ppm
- Requirement of bulbs for seed production: 1500 kg/ha (2.5-3cm in diameter)
- Pre emergence herbicide: Pendimethalin 30 EC @ 3.5 lit/ha or Oxyflurofan 0.15 EC @ 0.25 kg/ha
- Critical period of crop: Weed competition 30-60 days after planting
- Yield reduction is due to weeds:71.2%
- Best time to harvest Rabi onion is 1 week after 50-70%
- Yield and Harvesting season:
  - Rabi: 25-30 t/ha (April to May)
  - Kharif: 15-20 t/ha (Jan
- Kharif crops do not store
- Storage losses of onion

- ★ Onion post harvest losses: 30-60%
- ★ Reduction of sprouting : Gamma rays @ 60Gy
- ★ Onion bulbs stored at 0-4.5°C
- ★ Best bulb storage temperature: 0°C at 60-75% RH
- ★ Ideal TSS content for dehydration industry: >18%
- ★ Preferable onion bulb colour for dehydration industry: White
- ★ Desirable drying ratio for onion: 6:1
- ★ Indian varieties have drying ratio: 10:1
- ★ Ideal pyruvic acid for dehydration industry: 0.50-0.70%
- ★ For getting best quality onion seed, bulb to seed method is followed
- ★ For getting higher yield of onion seed, seed to seed method is followed
- ★ Average seed yield: 800-850 kg/ha
- ★ Bulb colour is governed by 5 major genes (ICGLR)
- ★ Black seed colour is controlled by single dominant gene
- ★ Bulb shape is governed by multiple genes
- ★ Downy mildew is controlled by single recessive gene

Varieties of onion:

Varieties	Breeding methods	Special features
Palam Lohit		New onion variety
IARI, New Delhi		
Pusa Riddhi	-	High Antioxidant variety
Pusa Soumya	-	1st bunching onion variety
Pusa White Flat	-	-
Pusa White Round	-	-
Pusa Madhvi	Selfing and massing	
Pusa Ratnar	-	-
Pusa Red	-	-
IIHR, Bengaluru		
Arka Vishwas	-	Suitable for growing in Rabi season and suitable for export
Arka Swadista	White colour onion	Suitable for bottle preservation
Arka Sona	-	Suitable for growing in Rabi season and suitable for export
Arka Pitambhar	Suitable for kharif and Rabi seasons Tolerance to purple blotch, basal rot diseases and thrips	
Arka Lalima (F_1)	Male sterile line (CMS)	Tolerance to purple blotch, basal rot & thrips
Arka Kirthiman (F_1)	Male sterile line (CMS)	
Arka Kalyan(Sel-14)	-	Moderately resistant to purple blotch & Suitable for kharif season
Arka Bheem (Syn-6)	-	Tri-Parental Synthetic Variety
Arka Akshay (Syn-4)	-	Tri-Parental Synthetic Variety
DOG, Rajagurunagar, Maharashtra		
Bhima Raj	Dark red	-
Bhima Dark Red	-	-
Bhima Kiran	-	-
Bhima Shakti	-	-
Bhima Shwata	White colour	-
Bhima Shubra	White colour	-
Bhima Safed	White colour	-
MPKV, Rahuri, Maharashtra		
Phule Safed	White onion	-
Phule Swarna	Yellow onion	-
Phule Samarath	-	-
Aggregatum onion	CO-(On)-5	Propagation by seeds

Important variety with specific purpose:

- ★ Multiplier onion varieties: CO-1, 2,3,4, CO-(On)-5, MDU-1, Agrifound Red, Arka Ujjwal
- ★ Recommended variety of yellow onion variety: Mercedes, Cougar, Lin
- ★ Most suitable variety for dehydration: Punjab-48 (TSS: 14.6%)
- ★ White onion varieties have low TSS: 10-14%
- ★ Selfing and massing through developed variety
- ★ Suitable varieties for hilly areas: Brown S
  Lockyar Brown
- ★ Yellow coloured onion bulb varieties: Ear

- ★ Onion hybrids using CMS system: Arka Kirtiman and Arka Lalima
- ★ Suitable for export purpose: Red Creole, Granex, Bombay Red, Yellow Bermuda, Patna Red
- ★ Dehydration varieties: Punjab-48, White Imperial Spinach, Rivrina Late Brown, Country Queen
- ★ Yellow skinned cultivars: Early Grano, Bermuda Yellow
- ★ White colour variety of onion: Punjab-48 and Udaipur-102
- ★ Long day variety: Brown Spanish
- ★ Resistant to thrips: N-53 and Pusa Ratnar
- ★ Suitable for both kharif and rabi season: Arka Niketan
- ★ Suitable for kharif season: N-53, Arka Kalyan, Agrifound Dark Red, Baswant-180 and N-2-4-1
- ★ Recommended variety for green onion: Pusa Soumya, Early Grano
- ★ Resistant to purple blotch: Italian Red and Local Brazilian
- ★ Suitable for salad purpose: Early Grano
- ★ Suitable for export, particularly to Malaysia and Singapore: Arka Bindu and Agrifound Rose
- ★ Most favourable temperature for purple blotch (*Alternaria porri*) of onion is 28-30°C with 80-90% RH

Diseases and pest of onion:

Diseases	Causal organism	Special features
Purple blotch	*Alternaria porri*	Seed borne, Serious foliar disease
Bottom rot/Basal rot	*Fusarium oxysporium*	Seed borne
Black mould	*Aspergillus niger*	Most common post-harvest storage disease
Stemphylium blight	-	Major problem in field
Downy mildew	*Peronospora destructor*	Soil borne disease
Onion smut	*Urocystis capsulae*	
Yellow dwarf	MLOs	Vector: Aphids or mechanical
Aster yellow	Virus	
Aspergillus and *Penicillium* rot		Most important storage diseases of onion in India
Pests:		
Onion thrips	*Thrips tabaci*	Major pest in the world
Onion fly	*Delia antique*	-
Onion mite	*Aceria tulipae*	-
Nematode:		
Onion bulb and stem nematode	*Ditylenchus dipsaci*	-

2. LEEK

2. **Leek:** *Allium porrum*: 2n=4X=32: Alliaceae: Origin: Mediterranean region
- ★ Leek is a non-bulb forming member of onion family
- ★ Leek is a favourite vegetable in kitchen garden
- ★ Economic part: Blanched stem and leaves
- ★ Blanching is an important practice in Leek
- ★ Varieties: London Flag and American Flag
- ★ Palam Paushtik- 1st indigenous variety in India
- ★ Plant of leek is larger than onion
- ★ Leek is a biennial crop for seed production

3. GARLIC

3. **Garlic:** *Allium sativum*: 2n=2X=16: Alliaceae: Origin: Central Asia
- ★ Garlic is the 2nd most important bulb crop in India
- ★ China ranks 1st in area and production of area and production in the world
- ★ Highest area and production in India: Madhya Pradesh
- ★ Highest productivity in India: Jammu and Kashmir (13.91t/ha)
- ★ Garlic in India:2.62 lakh/ha, production: 14.25 lakh/ha, productivity: 5.44 t/ha
- ★ Garlic has a higher nutritive value than other bulb crops
- ★ Flavour of garlic cloves is more powerful than other bulb crops
- ★ Ayurveda, Garlic is considered as "Nectar of Life"
- ★ Garlic produced only in one season *i.e.* Winter season (Rabi)
  - ✦ Ancestor of garlic: *Allium longicupis*
  - ✦ Chinese Garlic: *Allium macrostemon*
  - ✦ Crow Garlic/Wild garlic: *Allium vineale*
  - ✦ Field Garlic: *Allium oleraceum*
  - ✦ Non-bolting Garlic: *Allium sativum var. sativum*
  - ✦ Bolting Garlic: *Allium sativum var. ophiosorodon*
  - ✦ Meadow Garlic/Wild Onion/Wild Garlic: *Allium canada*
- ★ Frost hardy plant
- ★ Sexually sterile diploid plant

★ In India, mostly grown varieties are short day garlic types
★ Curing is done to remove excess moisture
★ Export quality garlic size should be 40-60 mm with 10-15 cloves
★ Commercial propagation: cloves
★ Required cloves: 350-500 kg/ha
★ Critical day length for bulbing in garlic is 12 hrs
★ Allicin is the antibacterial substances of garlic and has the typical odour of fresh garlic
★ True Garlic flavor is due to diallyl disulfide
★ Recovery of cloves in the garlic bulbs ranges from 86-96%

Varieties:

★ **NHRDF, Nasik :**
- Agrifound White (G-41)
- Agrifound Parvati-1(G-313)
- Agrifound Parvati-2 (G-408)
- Yamuna Safed-1 (G-1)
- Yamuna Safed-2 (G-50)
- Yamuna Safed-3 (G-282)
- Yamuna Safed-4 (G-323)
- Yamuna Safed-5 (G-189)

★ **DOG, Rajagurunagar, Maharashtra**
- Bhima Omkar
- Bhima Purple

★ **Other varieties:**
- Pant Lohit
- HG-17
- Ooty-1

★ **Specific features of important variety:**
- Among most of cultivars available, Jamnagar Local cultivar of garlic having largest bulb size
- G-282: Big size clove and early variety, suitable for export purpose
- Exotic variety: Creole, Italian and Tahiti
- Tolerant to purple blotch disease, long day variety, suitable for cultivation in hills for northern states: Agrifound Parvati (G-313)
- Long day variety of garlic: Agrifound Parvati (Hard neck type)- Suitable for North Indians
- Short day varieties: Godavari, Shweta, G-1 (Yamuna Safed), Bhima Omkar and Bhima Purple

★ Export quality bulb: 40-60 mm diameter with 10-15 cloves in each bulb
★ Average yield: 8-10 t/ha
★ Bulb sprouting is due to excessive N_2 and soil moisture
★ Bulb splitting is due to delaying of harvest

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H. Root Vegetable Crops

1. Carrot
2. Radish
3. Beetroot
4. Turnip

★ **Commercially important root crops:** Radish, carrot, beetroot and turnip
★ **Commercially less important root crops:** Parsnip, rutabaga, salsify, chervil, skirret and celeriac
- **Rutabaga:** *Brassica napobrassica*
- **Parsnip:** *Pastinaca sativa* 2n=22
- **Horseradish:** *Armoracia rusticana*
- **Chervil:** *Anthriscum cerefolium* 2n=32
- **Celeriac:** *Apium graveolens* var. *rapaceum* 2n=22
- **Skirret:** *Sium sisarum* 2n=12
- **Salsify:** *Tragopogon porrifolius*

1. CARROT

1. **Poor man's gingeng/Carrot:** *Daucus carota*: Apiaceae (Umbelliferae): 2n=2X=18: Origin: South West Asia (Afghanistan)

★ Isocoumarin is responsible for bitter flavour in carrot
★ Tropical red carrot used for sweet preparation is called *Gajar Halwa* is very famous in North India
★ China is the leading producer of carrot
★ Afghanistan is the centre of diversity of the purple carrot (anthocyanin carrot)
★ Edible portion is enlarged fleshy taproot
★ The taste of carrot is mainly due to presence of glutamic acid
★ Carrot roots rich in sucrose *i.e.* 10 times more than glucose and fructose
★ *Kanji*- an appetizing drink is prepared from Asiatic black carrot root
★ The Daucus carota and Daucus sativus are only cultivated species
- Queen Ann's Lace (wild carrot): *Daucus carota ssp. carota*

★ *Daucus capillifolius*: only species crossable with culti
★ Carrot is cool season crop

- Related vegetables of carrot family: Skirret, Parsnip, Ceraliac and Chervil
- Optimum temperature for carrot root formation: 18-22°C
- Optimum temperature for carrot seed germination: 7.2-23.9°C
- Optimum temperature for European carrot bolting: 5-8°C for 40-60 days
- Best temperature for orange root colour development of carrot is 15.6-21.1°C
- Carrot seed oil is commercially used in France
- **Carrot pigmentation:**
  - Red colour of carrot → Lycopene
  - Orange colour of carrot → β-carotene
  - Purple colour of carrot → Anthocyanin
  - Yellow colour of carrot →Xanthophyll (Lutein)
- Higher accumulation of carotene occurs in older cell of the phloem
- Carotenoids in carrot is accumulated in chromoplast
- High carotene mass (HCM) varieties have higher carotene content: >500 ug/g or 500 ppm
- The high level of β-carotene enhanced using phenotypic recurrent selection breeding method
- Total carotenoid ranges from 80-120 ppm
- β-carotene percentage in carrot root: 50%
- Anthocyanin content of black carrot ranges from 1750 mg/100g
- Average range of phytonutrients in carrot:
  - β-carotene: 60-500 ppm
  - Lycopene: 50-100 ppm
  - Lutein: 1-5 ppm
- Hispid branches produced from 2nd year
- Carrot is an annual herb for root production and biennial for flowering and fruit set
- Good quality carrot contains maximum cortex and minimum core
- Type of fruit: Schizocarp
- Type of inflorescence: Compound umbel
- Carrot flower is protandrous in nature
- Carrot is highly cross pollinated crop due to Andromonoecy, protandry and male sterility
- Over 95% of cross pollination has been observed in carrot
- Family breeding is type of recurrent selection strategy used for trait improvement in carrot
- Carrot doesn't need earthing up operation
- Seed rate: 5-6 kg/ha
- Sowing time:
  - Asiatic type: August to January in North Indian plains
  - European type: September to March

- Carrot seeds germinate within 1 week
- Carrot seed contain germination inhibitor: Carrotal
- Maximum concentration of carotene in carrot 90-130 days after planting
- Chantenay: excellent variety for canning and storage
- Purple or red asiatic carrots having anthocyanin and lycopene are useful antioxidants
- Carrot is gross feeder of potash (K)
- Forking of carrot is due to undecaying manures
- Baby carrot: Breed for supermarket purpose: e.g. Paris Market
- Carrot has high reproduction potential 50,000 seeds/plant
- Seed yield: 500-600 kg/ha
- Poole (1937) was 1st reported heterosis in carrot
- Three systems of Cytoplasmic male sterility (CMS) a) Brown anthers b) Petaloid Stamen c) Gummifer types
- Brown anther CMS 1st found in Tender Sweet variety
- Petaloid stamen CMS 1st found in Cornell wild carrot
- Commonly used for hybrid seed production: Petaloid type of CMS
- Root shape in carrot is governed by 3 Genes (D, N, P)

Pest and diseases

- Lygus Bug is a serious pest of carrot for seed crops
- Carrot yellows is virus disease transmitted through 6 spotted leaf hopper (*Macrosteles fascifrons*)
- Carrot root knot nematode: *Meloidogyne hapla*

Difference between Asiatic and European carrot:

Asiatic carrot/Desi/Red colour carrot (*syn.* Tropical carrot, Eastern carrots, Anthocyanin carrot)	**European carrot/orange colour carrot** (*syn.* Western carrot, Temperate carrot and Carotene carrot)
Heat tolerant	Cold tolerant
Deep red or purple coloured	Orange coloured
High yielding and low in carotene	Rich in carotene
Produce seed under tropical condition	Produce seed only ter
More anthocyanin pigments	Le
Annual for root and seed production	
Core is distinct	

Varieties of carrot

Varieties	Special features
1. Tropical Carrots	
Pusa Vasuda	1st tropical carrot hybrid using CMS system (Petaloid type)
Pusa Asita	1st Black colour carrot variety in India
Pusa Vrishti	Tolerant to heat and humidity and suitable for kharif sowing
Pusa Rudhira	Red- Self colour core variety
Pusa Meghali	Highest vitamin-A variety Seed production in the plains (orange colour root)
Pusa Kesar	Tolerant to high temperature Seed production in the plains
Pusa Kulfi	Cream/yellow root colour
2. European carrots	
Pusa Nayanjyoti	F_1 Hybrid 1st Temperate carrot hybrid developed using CMS
Pusa Yamadagni	Self-coloured core variety
Imperator	Mid season to late maturing cultivar
Chantenay	Excellent cultivar for canning and storage
Zeno	Introduction from Germany-Suitable for Nilgiri hills
Royal Chantenay	Well suited variety for home garden
Danvers	Suitable for both fresh and processing
Oxheart	Heart shaped roots

- ★ Heat tolerant carrot: Kuroda and New Kuroda (Japan) having deep orange and stumped roots
- ★ Exotic cultivars commercially growing in India: Chantenay, Danvers, Nantes, Early Horn and Early Gem
- ★ Nematode-resistant carrot: Brasilia, source of resistance species: *D. carota subsp. hispanicus*

Physiological disorders of carrot:

Physiological disorders	Causes
Carrot splitting	Excessive N_2 + Boron deficiency + Change in soil moisture
Cavity spot	Excessive N_2 + Ca deficiency + Change in soil moisture
Bitterness	High ethylene production
Forking	Hard soil pan

2. RADISH

2. **Radish:** *Raphanus sativus*: Brassicaceae: 2n=2X=18: Origin: Mediterranean region

- ★ Radish root develops from primary root and hypocotyl
- ★ Asiatic radish is originated from *Raphanus sativus* f. *raphanistroides*
- ★ European radish is originated from *R. Raphanistrum, R. maritimus, R. laundra* and *R. rostratus*
- ★ Botanical varieties of radish was given by Banga (1976)
  - + Garden/European/Occidental/Small cool season radish: *Raphanus sativus var. radicula*
  - + Oilseed Radish/Fodder radish: *Raphanus sativus var. oleiferous* (South America)
  - + Rat-tail/mougri radish: *Raphanus sativus var. caudatus*, pods are used as vegetable in India
  - + Large radish/Black/ Spanish Radish: *Raphanus sativus var. niger*
  - + Japanese/Chinese Winter Radish: *Raphanus sativus var. raphanistroides*
  - + Indian Radish: *Raphanus indicus*
  - + Chinese Radish: *Rhaphanus sativus var longipinnatus*
- ★ All 4 types of botanical varieties belongs to *Raphanus sativus*, they are freely intercrossable
- ★ Horse radish is botanically known *Armoracia rusticana*, 2n=32
- ★ Radish is a good source of vitamin-C (15-40 mg/100g)
- ★ Radish is an ancient root crop
- ★ Suitable intercrops or companion planting
- ★ The fleshy root radish is modified form of root is known as fusiform
- ★ The edible portion of radish root develops from both primary root and the hypocotyl
- ★ Major sugar present in radish: Glucose
- ★ Famous Japanese radish pickle: Takoan
- ★ Indigenous type of radish is more pungent than European type of radish
- ★ Radish pungency is due to 4-methylthio-3-butenyl isothiocyanate (MTB-ITC).
- ★ Major glucosinolates in radish is isothiocyanates (tran-4-methyl-thiobuentyl isothiocynate)

Pigmentation in radish:

- + Pink, red, purple colour is due to anthocyanin pigments
- + Purple colour: Cyanidin
- + Red colour: Pelargonidin (raphanusin)

- ★ Red fleshed winter cultivars of radish have anthocyanin ra[illegible] 12.2 t[illegible]
- ★ Pink-skinned radish: rich source of ascorbic acid

- Type of inflorescence: Terminal Raceme
- Fruit: Indehiscent pod type *i.e. Siliqua*
- No problem of seed shattering
- Suitable temperature for radish cultivation 10-15°C
- Radish roots develop best flavour, texture and size at 10-15°C
- Seed viability: 4-5 years
- Pseudo self-incompatibility is observed in Radish
- Radish is cross pollinated (entomophilous) crop and honey bees are important pollinator
- Radish is a cross pollinated vegetable due to sporophytic self-incompatibility
- Cylindrical root shape preferred for mechanical harvesting
- Radish is useful for curing liver and gall bladder of problem
- Seed rate:
  - Tropical types: 8-10 kg/ha
  - Temperate types: 10-12 kg/ha
- *Varieties*: Bombay Red, Chinese Rose, Contai
- Japanese varieties: Sakurajuma
- Japanese White variety set seeds in plains
- Seed yield: 600-800kg/ha
- For nucleus seed production root to seed method is preferred
- Male sterility in Radish 1st reported in Japanese radish types by Ogura (1968)
- Radish CMS system: 1. Ogura type and 2. Kosana type
- Ogura system of CMS is commercially utilized for hybrid seed production
- *orf-138* (Ogura CMS) is a mitochondrial gene responsible for CMS in radish

Varieties:

Asiatic Varieties	European Varieties
1. Pusa Desi	1. Pusa Himani (Radish Black × Japanese White)
2. Pusa Reshmi (Green type × Desi type)	2. Rapid Red White Tipped-Globular/round form
3. Pusa Chetki	3. Scarlet Globe-Round shape roots
4. Pusa Safed: White-5 × Japanese White	4. Scarlet Long
5. Arka Nishant-Multiple disease resistance	5. Pusa Mridula (Extra early and table purpose variety)
6. Chinese Pink: Dual season variety (Hills and Plains)	6. White Icicle- Tender variety

Other varieties: China Rose, Japanese White, CO-1, Punjab Safed	
IIVR Varieties: Kashi Sweta, Kashi Hans	
New Varieties: Palam Hriday, Pusa Jamuni, Pusa Gulabi	

Special features of important variety:

- Pusa Shweta: New variety
- Globular or round varieties: Rapid Red White Tipped (RRWT), Scarlet Globe, French Breakfast
- Green shoulder radish variety: Pusa Shuka
- 1st purple fleshed variety in India: Pusa Sagarika
- Long staying capacity (White colour variety): Pusa Vidhu
- Suitable for growing in kitchen gardens, container gardens: Pusa Mridula
- Only variety which can be grown throughout the year: Pusa Himani
- Popular variety in North India: Hill Queen
- Giant variety more than 1m long: Jaunpuri or Giant radish or Newari
- Resistant to Pithiness, pre-mature bolting, root branching and forking: Arka Nishant

Pest and diseases

- Most serious pest: Aphids
- Mustard saw fly (*Athalia lugens proxia*) is the most common occurring pest in radish
- Radish phyllody is a serious problem in seed production
- Yellow disease: *Fusarium oxysporum* f. sp. *conglutinans* race 2
- Clubroot is a soil borne disease caused by *Plasmodiophora brassicae*
- White rust: *Albugo candida*

Physiological disorders

- Pore extent: Pores are formed by the collapse of parenchymatous cells in root tissue, caused by excessive root growth
- Pithiness of root is more in summer crop and is due to excess NPK and soil moisture stress
- Hollow rot is physiological disorder of radish due to high tempera... 16-30days of sowing
- Wart is due to soil moisture deficit
- Akashin is caused by boron deficiency

3. BEETROOT

3. Beetroot: *Beta vulgaris*: 2n=2X=18: Family: Chenopodiaceae: Origin: Mediterranean region
   - ★ Beetroot is rich source of folic acid, essential for pregnant women to reduce risk of spina bifida
   - ★ Garden beet, sugar beet, swiss chard, mangel, palak all belongs to same genus and species
   - ★ Garden beet originated from *Beta vulgaris ssp. maritima* × *B. patula*
     - Leaf beet chard: *Beta vulgaris* ssp. *cicla*
     - Garden beet/fodder beet/sugar beet: *Beta vulgaris* ssp. *vulgaris*
     - Ancestor of beetroot: Sea beet- *Beta vulgaris* ssp. *maritima*
     - Beet root and sugar beet are cross compatible
   - ★ Non horticultural forms of beetroot: Sugarbeet, mangold and fodder beet
   - ★ Pigmentation in beetroot:
     - i. Red-violet colour of beetroot → β-cyanins pigment
     - ii. Yellow colour of → β-xanthins pigment
   - ★ Type of inflorescence: Large spike which is normally develops 2nd year
   - ★ Beetroot is wind pollinated (anemophilous) crop
   - ★ Self sterility in beet is overcome by sib mating
   - ★ Type of inflorescence: Spike
   - ★ Seed type: Multigerm or seedball
   - ★ Beetroot fruits contain 5-6 seeds
   - ★ In beetroot each seedball produces 2-6 plants
   - ★ 1g of seed ball contains 50 seeds
   - ★ Seed viability under normal storage condition: 5-6 years
   - ★ Seed rate: 7-9 kg/ha
   - ★ Staggered sowing commonly recommended for beetroot
   - ★ Thinning (2 thinning) is essential practice in beetroot
   - ★ All cultivars of beetroot are biennial and temperate types grown in India
   - ★ Vernalization temperature for beetroot: 4-10°C for 2 weeks
   - ★ In Beetroot, temperatures of 4.5-10°C for 15 days induce premature bolting
   - ★ Seed production in India: Only hills
   - ★ Beet root most productive at 20-22°C
   - ★ Beet roots are harvested when they attain a diameter of 3.5cm

Varieties:

- ✦ Detroit Dark Red, Crimson Globe, Crosby Egyptian, Early Wonder, Ooty-1, Ochio canner
- ✦ Avon Early: Bolting resistant cultivar and resistant to downy mildew (*Peronospora farinose* f. sp. *betae*)
- ✦ Khavskaya: Mid season and Monogerm cultivar (Unilocular seedball)
- ✦ Early maturing beetroot variety: Crosby Egyptian and Early Wonder
- ★ Poor colour development in beetroot is due to high temperature

Pest and disease:

- Beet mosaic yellow virus is transmitted by aphids
- Curly top virus is transmitted by hoppers
- Cercospora leaf spot: *Cercospora beticola*

Physiological disorders

- ★ Zoning is the physiological disorder of beetroot due to high warm weather
- ★ Internal black spot or brown heart or heart rot or crown rot is due to boron deficiency
- ★ The boron deficiency is common in alkaline soils. Overcome by liming often brings about boron deficiency

4. TURNIP

4. Turnip: *Brassica rapa* var. *glabra:* Brassicaceae: 2n=2X=20: Origin: Mediterranean region
   - ★ Turnip is botanically modified form of root is known as 'napiform'
   - ★ Fleshy thickened underground portion of turnip is actually swollen hypocotyl
   - ★ The young leaves are rich source of ascorbic acid, iron and Vitamin A are used as greens
   - ★ Tolerant to frost and freezing temperature
   - ★ Turnip is closely related to Swede (*Brassica napus* var. *napobrassica*)
   - ★ Swede or rutabaga or sweet turnip: *Brassica napus* var. *napo* Amphidiploid ;2n ; AACC genome
     - ✦ Natural hybridization between *B. campestris* ea (2n=18,
     - ✦ Edible part: Enlarged tap root
   - ★ Type of inflorescence: Terminal Raceme
   - ★ Honey bees are chief pollinating agent
   - ★ Dry matter
   - ★ The
   - ★ erature

- ★ Viability of turnip seeds: 5-6 years
- ★ Normally turnip seed germination takes about 4-6 days
- ★ Seed yield: 550kg/ha
- ★ Turnip classification is given by Shoemaker (1949)
- ★ Major problem in seed production: Phyllody disease
- ★ Turnip yellow mosaic virus (TYMV) is transmitted by flea beetle
- ★ Alternate host for TYMV is cabbage
- ★ Turnip crinkle is viral disease

Varieties of turnip :

Tropical types		Temperate types	
Varieties	**Skin Colour**	**Varieties**	**Skin Colour**
1. Pusa Kanchan	Red colour	1. Pusa Swarnima (Japanese White × Golden Ball)	Creamy yellow skin
2. Pusa Sweti	Pure white	2. Pusa Chandrima (Japanese White × Snow Ball)	Pure white
3. Punjab Safed-4	Pure white	3. Snowball	White
-	-	4. Golden Ball	Bright creamy yellow skin
-	-	5. Purple Top White Globe	Bright purple on top and Lower half white
-	-	6. Early Milan Top	Purplish red at top and White at lower portion

Specific features of important variety:

- ★ Early Milon Red Top is an extra early and high yielding cultivar reaching maturity in 45 days
- ★ Foliage Cultivars: Sevan Top, Flat Japan, Shogoin
- ★ Clubroot resistant turnip cultivar: Manga from New Zealand
- ★ Turnip var. Pusa Kanchan sets seeds in plains
- ★ Pusa Sweti: Off season variety

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I. Tuber Vegetable Crops

1. Potato
2. Sweet potato
3. Tapioca
4. Yama
5. Elephant food yam
6. Taro

1. POTATO

1. **King of vegetables/Poor man's friend/Poor man's strength:** *Solanum tuberosum*: Solanaceae: 2n=4X=48: Origin: South America

- ★ *Solanum tuberosum* L., is a auto tetraploid (2n=4x=48) or segmental allopolyploidy
- ★ It ranks as the 4th major food crop of the world, exceeded only by wheat, rice, and maize.
- ★ Potato is the third most important food crop in the world after rice and wheat
- ★ Freshly harvested potato contains 80% water and 20% dry matter
- ★ Potato is a dicot plant
- ★ Potatoes are rich source of CHO (22.6%)
- ★ Potato tubers borne at stolon ends
- ★ Basically a crop of temperate regions
- ★ Stable food in Ireland
- ★ Potatoes are alkaline yielding food
- ★ Percentage of starch: 60-80%
- ★ Potato introduced in India 17th century by Portuguese
- ★ Potato being a labour-intensive crop (145 man days for cultivation of one ha of land)
- ★ Nearly 85% potato in the country is produced in North Indian plains
- ★ About 95% of the national potato is harvested in Rabi season
- ★ Long day plant but cultivated as short day plant in India
- ★ Current share of potato to agricultural GDP is 2.86%
- ★ Highest productivity of potato in world: New Zealand
- ★ India ranks 4th in area and 3rd largest producti
- ★ At present in India, about 68%
  utilized as seed (8.5%) and
- ★ India annual potato pr
- ★ Potato consumption
- ★ Potato is grown in

- Highest area and the production: Uttar Pradesh
- Leading potato producing states: Uttar Pradesh (33%) > West Bengal > Bihar
- Highest productivity: Madhya Pradesh (30.8 t/ha)
- Leading potato producing countries in world: China > India (11.4%) > Russia
- Europe is the largest per capita consumer followed by North America and Latin America
- The year 2008 was declared as the International Year of Potato (IYP) by the United Nations
- On a dry weight basis, the protein content of potato is similar to that of cereals and is very high in comparison with other roots and tubers
- Potato supplies about 2 ½ times more calories than wheat and rice
- About 90% of the potato crop in India is cultivated on Indo-Gangetic Plains
- Main planting of potato in Indo-Gangetic plains: October-March
- Indian processing industry consume 2% of potato for processing
- Optimum temperature for formation periderm during storage: 15-20°C
- Optimum temperature require for tuberization in potato is 20°C
- Most potato genotypes tuberize decline when the night temperature is more than 23°C
- Generally potato crop is raised in India when maximum day temperature is below 35°C and night temperatures below 20°C.
- Ideal temperature for potato sprouting: 22-34°C
- Potato starts sprouting stored at temperature of 10-20°C
  - Diploid species: *Solanum phureja* and *Solanum stenotomum*
  - Pentaploid species: *Solanum* × *curtilobum* (2n=60)
  - Resistant to late blight: *Solanum desmissum*
  - Durable resistance to late blight: *Solanum bulbocastanum*
  - Resistance to potato cyst nematode: *Solanum vernei*
  - Lack of tuber blackening: *Solanum hjertingii*
- Potato commonly grown in North Indian plains: October to March
- Potato is a self-pollinated crop but vegetative propagated through tuber
- About 90% of disease free seed potato is produced in Punjab, specially Jalandhar district
- Seed plot technique (SPS) was given by Pushkarnath (1965)
- Seed plot technique (SPS) was developed by CPCRI for multiplication of seed tubers free from viruses in North Indian Plains
- Seed rate: 800-1500 kg/ha of seed tubers
- Seed tubers account about 40-50% of the total input cost
- True Potato Seed (TPS) concept was given by Dr.S.Ramanujan
- TPS is botanical seed produced through sexual reproduction

- TPS seed rate: 100-120 g/ha
- Low seed multiplication ratio: 1:6
- Potato water requirement: 400-600 mm
- Potato 3 crops/year in Nilgiri Hills
- Potato harvesting time in plains: January-February
- Potato harvesting in North Hills: September-October
- Harvesting of potato done at <30°C to avoid charcoal rot disease
- Potato is a semi-perishable commodity
- Warehouse potato stored at : 8-10°C, 80% RH
- Best method storage for potato: Cold storage
- Best cold storage temperature for seed potato: 2-4°C, 75-80% RH to check the sprout
- Storage of seed potato: 2-4°C under cold storage
- Table and processing potato stored at high temperature: 10-12°C long term (6-8 months)
- Suberization: Heavy of wounds dry hardening by formation of periderm
- Suberization temperature: 25°C, 95% RH
- Potato naturally flowers: cool climate and long-day conditions with > 15hours light
- Potato tubers have a dormancy of nearly 8-10 weeks
- Potato tuber dormancy broken by soaking tubers in 1% Thiourea+1 ppm GA_3 @ 1hours
- Potato dehaulming is done before aphid population reaches the critical level *i.e* 20 aphids/100 compound leaves
- Most common used sprout suppressant in potato: CIPC (Isopropyl N-3-chlorophenyl carbomate) or chloropropham 25mg *a.i*/kg of tubers
- Protein rich transgenic potato has been developed by protein synthesizer gene *AmA1* (storage protein gene)
- Protein synthesizer gene was isolated from *Amaranthus hypochondriacus*
- Gene resistant to potato tuber moth and leaf eating caterpillar: *Cry-1 (Bt)* gene
- Aeroponics: growing plants in an air mist environment without soil or an aggregate medium
- Golden cyst nematode (*Globodera rostochinensis*) is major problem in Southern Hills
- International Potato Centre (CIP) is located at Lima in Peru, started in 1971
- All India Coordinated Potato Improvement Project (AICPIP) started in 1971, HQ in Shimla, HP
- Central Potato Research Institute (CPRI) is located at

3. BEETROOT

3. **Beetroot:** *Beta vulgaris*: 2n=2X=18: Family: Chenopodiaceae: Origin: Mediterranean region
   - ★ Beetroot is rich source of folic acid, essential for pregnant women to reduce risk of spina bifida
   - ★ Garden beet, sugar beet, swiss chard, mangel, palak all belongs to same genus and species
   - ★ Garden beet originated from *Beta vulgaris ssp. maritima* × *B. patula*
     - Leaf beet chard: *Beta vulgaris* ssp. *cicla*
     - Garden beet/fodder beet/sugar beet: *Beta vulgaris* ssp. *vulgaris*
     - Ancestor of beetroot: Sea beet- *Beta vulgaris* ssp. *maritima*
     - Beet root and sugar beet are cross compatible
   - ★ Non horticultural forms of beetroot: Sugarbeet, mangold and fodder beet
   - ★ Pigmentation in beetroot:
     - i. Red-violet colour of beetroot → β-cyanins pigment
     - ii. Yellow colour of → β-xanthins pigment
   - ★ Type of inflorescence: Large spike which is normally develops 2nd year
   - ★ Beetroot is wind pollinated (anemophilous) crop
   - ★ Self sterility in beet is overcome by sib mating
   - ★ Type of inflorescence: Spike
   - ★ Seed type: Multigerm or seedball
   - ★ Beetroot fruits contain 5-6 seeds
   - ★ In beetroot each seedball produces 2-6 plants
   - ★ 1g of seed ball contains 50 seeds
   - ★ Seed viability under normal storage condition: 5-6 years
   - ★ Seed rate: 7-9 kg/ha
   - ★ Staggered sowing commonly recommended for beetroot
   - ★ Thinning (2 thinning) is essential practice in beetroot
   - ★ All cultivars of beetroot are biennial and temperate types grown in India
   - ★ Vernalization temperature for beetroot: 4-10°C for 2 weeks
   - ★ In Beetroot, temperatures of 4.5-10°C for 15 days induce premature bolting
   - ★ Seed production in India: Only hills
   - ★ Beet root most productive at 20-22°C
   - ★ Beet roots are harvested when they attain a diameter of 3.5cm

Varieties:

- ✦ Detroit Dark Red, Crimson Globe, Crosby Egyptian, Early Wonder, Ooty-1, Ochio canner
- ✦ Avon Early: Bolting resistant cultivar and resistant to downy mildew (*Peronospora farinose* f. sp. *betae*)
- ✦ Khavskaya: Mid season and Monogerm cultivar (Unilocular seedball)
- ✦ Early maturing beetroot variety: Crosby Egyptian and Early Wonder
- ★ Poor colour development in beetroot is due to high temperature

Pest and disease:

- Beet mosaic yellow virus is transmitted by aphids
- Curly top virus is transmitted by hoppers
- Cercospora leaf spot: *Cercospora beticola*

Physiological disorders

- ★ Zoning is the physiological disorder of beetroot due to high warm weather
- ★ Internal black spot or brown heart or heart rot or crown rot is due to boron deficiency
- ★ The boron deficiency is common in alkaline soils. Overcome by liming often brings about boron deficiency

4. TURNIP

4. **Turnip**: *Brassica rapa* var. *glabra:* Brassicaceae: 2n=2X=20: Origin: Mediterranean region
   - ★ Turnip is botanically modified form of root is known as 'napiform'
   - ★ Fleshy thickened underground portion of turnip is actually swollen hypocotyl
   - ★ The young leaves are rich source of ascorbic acid, iron and Vitamin A are used as greens
   - ★ Tolerant to frost and freezing temperature
   - ★ Turnip is closely related to Swede (*Brassica napus* var. *napobrassica*)
   - ★ Swede or rutabaga or sweet turnip: *Brassica napus* var. *napobrassica*: Amphidiploid :2n=38 ; AACC genome
     - ✦ Natural hybridization between *B. campestris* (2n=20, AA) × *B. oleracea* (2n=18, CC)
     - ✦ Edible part: Enlarged tap root
   - ★ Type of inflorescence: Terminal Raceme
   - ★ Honey bees are chief pollinating agents of turnip
   - ★ Dry matter content of turnip should be 8-9%
   - ★ The most favourable temperature for root 10-13°C air temperat... 18-23°C soil temperature
   - ★ Turnip has strong sporophytic SI
   - ★ In turnip temperatures below 10°C induces flow...
   - ★ Seed rate: 3-4 kg/ha
   - ★ Thinning is essential practice to maintain ...

★ Viability of turnip seeds: 5-6 years
★ Normally turnip seed germination takes about 4-6 days
★ Seed yield: 550kg/ha
★ Turnip classification is given by Shoemaker (1949)
★ Major problem in seed production: Phyllody disease
★ Turnip yellow mosaic virus (TYMV) is transmitted by flea beetle
★ Alternate host for TYMV is cabbage
★ Turnip crinkle is viral disease

Varieties of turnip :

Tropical types		Temperate types	
Varieties	**Skin Colour**	**Varieties**	**Skin Colour**
1. Pusa Kanchan	Red colour	1. Pusa Swarnima (Japanese White × Golden Ball)	Creamy yellow skin
2. Pusa Sweti	Pure white	2. Pusa Chandrima (Japanese White × Snow Ball)	Pure white
3. Punjab Safed-4	Pure white	3. Snowball	White
-	-	4. Golden Ball	Bright creamy yellow skin
-	-	5. Purple Top White Globe	Bright purple on top and Lower half white
-	-	6. Early Milan Top	Purplish red at top and White at lower portion

Specific features of important variety:

★ Early Milon Red Top is an extra early and high yielding cultivar reaching maturity in 45 days
★ Foliage Cultivars: Sevan Top, Flat Japan, Shogoin
★ Clubroot resistant turnip cultivar: Manga from New Zealand
★ Turnip var. Pusa Kanchan sets seeds in plains
★ Pusa Sweti: Off season variety

I. Tuber Vegetable Crops

1. Potato
2. Sweet potato
3. Tapioca
4. Yams
5. Elephant food yam
6. Taro

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Varieties	Breeding methods	Specific features
New variety:		
Kufri Sadabahar		High yielding variety
Kufri Himalini		Moderate resistance to late blight
Kufri Shaillja	-	Moderately resistant to late blight
Kufri Girdhari	-	Highly resistant to late blight
Kufri Himsona	-	Highly resistant to late blight
Early varieties (80-90 days)		
Kufri Chandramukhi	Seedling 4485 × Kufri Kuber	-
Kufri Jawakar	Kufri Neelamani × Kufri Jyoti	-
Kufri Laukar	Adina × Sarkov	-
Kufri Sheetman	Craigs Defiance X Phulwa	-
Kufri Khyati	-	-
Kufri Surya	-	Heat tolerant variety field resistant to leaf hoppers
Kufri Ashoka	EM/C-1020 × Allerfruheste Gelbe	
Medium varieties (90-100 days)		
Kufri Bahar	Kufri red × Gineke	-
Kufri Sutlej	Kufri Bahar × Kufri Alankar	Moderately resistant to late blight
Kufri Anand	PJ-376 PH/f-1430	Resistant to late blight and tolerant to frost
Kufri Arun	-	Field resistant to late blight, tolerant to frost
Kufri Pukhraj	Craig's Defiance × JEX/B-687	Moderately resistant to late blight
Kufri Pushkar	Field resistant to late blight, and moderately resistant to *Phoma* and early blight	
Kufri Lalima	Moderately resistant to early blight and resistant to PVY	
Kufri Kanchan	Field resistant to late blight, grown in Darjeeling hills	
Late varieties (100-110 days)		
Kufri Sindhuri	-	Suitable for dehydrated flakes and canning

Kufri Badshah	Moderate resistance to late blight, early blight and potato virus X
Processing variety:	
Kufri Frysona	Suitable for processing into French fries
Kufri Chipsona-3	Resistant to late blight, medium maturing variety
Kufri Chipsona-4	Early maturing, resistance to late blight
Kufri Surya	Early maturing, heat tolerant (20°C) and hopper-burn resistant potato variety

Varieties	Uses
Kufri Chipsona-1	Chips, French fries, flakes
Kufri Chipsona-2	Chips, flakes
Kufri Himsona	Chips, flakes
Kufri Surya	French fries, chips (from early crop)

Important varieties with special features:

- ★ Kufri Surya: Early maturing, heat tolerant (20°C) and hopper-burn resistant potato variety
- ★ Immune to wart and resistant to late blight: Kufri Jyoti, Kufri Kanchan and Kufri Sherpa
- ★ Kufri Jyoti: possessing major R-genes (vertical resistance) for late blight derived from *S. demissum*
- ★ Resistance to frost: Kufri Sheetman, Kufri Chipsona-2
- ★ Resistant to potato cyst nematode and late blight: Kufri Swarna and Kufri Thenmalai
- ★ Resistant to late blight, early blight, potato virus X: Kufri Badshah
- ★ Resistant to late blight: Kufri Jyothi, Kufri Giriraj, Kufri Shailja, Kufri Himalini
- ★ Kufri Giriraj and Kufri Shailja with horizontal resistance derived from *S. andigena*
- ★ Suitable for processing of light colour chips and finger fries: Kufri Chipsona-1, 2 and Kufri Frysona
- ★ Resistant to golden cyst nematode: Kufri Swarna and Kufri Dewa
- ★ Kufri Gaurav: nutrient and agronomic efficiency variety

Disease and pest of potato:

Diseases of potato		
Diseases	**Casual organism**	
Late blight	*Phytophthora infestans*	
Potato wart	*Synchytricum endobi*	

Black scurf	*Rhizoctonia solanii*	-
Dry rot	*Fusarium spp.*	Storage disease
Soft rot	*Erwinia carotovora*	-
Bacterial wilt	*Ralstonia solanacerum*	-
Potato scab	*Streptomyces spp.*	-
Wart		Serious disease in Darjeeling hills Resistant variety: Kufri Kanchan
Virus diseases:		
Potato leaf roll	*Virus*	Aphids
Latent or faint mosaic	*PV-X and S*	Aphids
Severe mosaic	*Virus*	Aphids
Pest:		
Aphids		Vector of potato virus
Cut worm	*Agrotis ipsilon*	
Potato tuber moth	*Pthorimea operculella*	30-70% damage during storage
Nematode:		
Golden cyst nematode	*Globodera rostochinensis*	Resistant variety: Kufri Swarna Serious problem in Nilgiri hills

Physiogical disorders of potato:

Physiological disorders	Causes
Greening	Exposure to sunlight
Internal brown spot	Moisture deficiency
Black heart	Poor ventilation
Hollow heart	Excessive N_2
Chilling injury	Low temperature- 0°C
Freezing injury	Low temperature- -1 to -2°C

2. SWEET POTATO

1. **Sweet potato/Irish potato/White potato:** *Ipomea batatus*: 2n=6X=60: Convolulaceae: Origin: Central America
   - ★ Herbaceous perennial but cultivated as annual
   - ★ Moderately drought tolerant
   - ★ Sweet potato is the cheapest source of calories
   - ★ Sweet potato is hexaploid crop
   - ★ Largest grower of sweet potato in the world: China
   - ★ In USA 60-70% of the sweet potato is utilized for human food
   - ★ Leading producer of sweet potato: Odisha > West Bengal > UP
   - ★ Orange-fleshed sweet potato (OFSP): to overcome Vitamin A deficiency in sub-Saharan Africa
   - ★ Orange flesh colour of tuber is due to β-carotene
   - ★ In India sweet potato is generally cultivated as a rainfed crop
   - ★ Sweet Potato grows best at temperature >24°C
   - ★ Ideal temperature for tuber formation: 20-30°C
   - ★ Required light intensity for tuber formation: 18,000-40,000 Lux
   - ★ Sweet potato is a short day plant
   - ★ Ideal day length for sweet potato flowering: 11.5 hrs
   - ★ Sweet potato contains carotene (orange flesh) ranges between 5.4-20 mg/100g
   - ★ Type of inflorescence: Cymose (Flower colour: White to purple)
     - ▪ Progenitor of sweet potato: *Ipomea trifida*
     - ▪ Suitable rootstock cultivar for flowering and seed set: Inducer (*Ipomea carnea* ssp. *fistulosa*)
   - ★ Turning of vine practices is done in sweet potato
   - ★ Verde, Kalmegh is sweet potato variety
   - ★ Highly cross pollinated crop; Pollinator: honey bees and bumble bees
   - ★ Sporophytic SI is observed in sweet potato
   - ★ Sweet potato is commercially propagated by vine cuttings
   - ★ Required cuttings for planting in 1ha: 40,000-50,000 cuttings/ha
   - ★ Pox and scurf is a disease severe in neutral and high pH
   - ★ CCC and SADH are the best PGRs used for increasing tuber yield

Pest and diseases:

- ★ Most widely occurring nematodes of sweet potato throughout the world
  - ☆ Rootknot nematode (*Meloidogyne incognita*)

☆ Reniform nematode (*Rotylenchulus reniformis*)

★ Most serious pest in sweet potato: Sweet Potato weevil (*Cylas formicarius*) severe damage in summer crop

★ Most widely distributed and commonly occurring storage disease: Soft rot/Rhizopus rot (*Rhizopus stolonifer*)

★ Growth crack of sweet potato disorder is due to moisture imbalance

Varieties	Hybrid/Clone	Salient features
Introduced variety: Triumph, Nancy Hall and Nancy		
H-41	Hybridization	Sweet, low fiber content
H-42	Hybridization	Sweet, low fiber content
Varsha	Double cross hybrid	-
Sree Nandhini	Clonal selection	Drought tolerant
Sree Vardhini	Clonal selection	Purple skin and yellow flesh
Sree Rethna	Hybridization	Purple skin and orange flesh
Sree Bhadra	Clonal selection	Excellent Trap crop for RKN
Sree Arun	Hybrid	
Sree Varun	Hybrid	
Sree Kanaka	Inter-varietal hybrid	Short duration , β-carotene rich variety
Gouri	Hybrid	Purple skin and orange flesh,
Sankar	Hybrid	-
Kishan	-	High starch content (29-30%)
Rajendra Sakarkand- 92	-	Suitable for flood prone area of North Bihar
Co - 3	-	Orange flesh-High β-carotene variety
Konkan Ashwini	Selection	-
Other varieties: Gold Rush, Centennial, Goutham, Sourin, Kalinga, Rajendra Sakarkand Series, Samrat, Co -1, Co - 2		

3. TAPIOCA

1. **Tapioca/Cassava/Manioc/Yucca:** *Manihot esculenta*: 2n=2X=36: Origin: Guatemala and Mexico (South America)

★ Perennial, monoecious shrub

★ Cassava is a drought tolerant crop shed leaves when go into dormancy

★ Photosynthesis of cassava is peculiar having a combination of C_3 and C_4

★ Major uses: Chips, sago and vermicelli

★ Main constitutent of cassava tuber is starch

★ Cassava starch is used as a filler material in paints, medicine and health drinks

★ Cassava starch is used as industrial raw material for production of alcohol and biodegradable plastic

★ Globally 60% cassava production is used for human food (Tropical Africa: 230cal/day/person and South America: 150-160cal/day/person)

★ Nigeria is the leading country in cassava production

★ Thailand and India are the main exporter of cassava starch in international market

★ Highest production and productivity in India: Tamil Nadu

★ Leading producer of sweet potato: TN > Kerala > AP

★ Commercial cassava industries for sago and starch located in India: Salem (TN) and Smalkot belt (AP)

★ Cassava 1st introduced in India: Kerala

★ Cassava is grown as rainfed crop in Kerala and Andhra Pradesh

★ Cassava is grown as an irrigated and rainfed crop in Tamil Nadu

★ Yellow colour of cassava tuber is due to presence of β-carotene, the precursor of vitamin-A

★ Bitter principle of cassava is cyanogenic (HCN) glucoside

★ Cyanogenic potential of different cassava cultivars ranging from 0.2-62.4mg HCN/100g

★ HCN acid in pulp: 41 mg/kg

★ Cassava is highly heterozygous

★ Type of inflorescence: Racemose

★ Cassava is monoecious, highly cross pollinated crop (protogynous)

★ Main pollinating agents: Insects

★ Most recommended length of cutting for planting is 15-30cm

★ Commercially propagation by stem cuttings

★ Ideal temperature for cassava stem sprouting: 28-30°C

★ True cassava seeds (TCS) technology has been developed at CTCRI, Kasargod

★ TCS seed rate: 1.5kg/ha

★ Viability of cassava seeds: 8 months
★ Cassava seed dormancy period: 3-4 months
★ Sago is a commercial product prepared from cassava
★ Staggered harvesting practised in cassava
★ Cassava mosaic virus (CMV) is most serious transmitted by whitefly (*Bemisia tabaci*)

Varieties of cassava:

Varieties	Hybrid/Clone	Remarks
H-7	Hybridization	Industrial variety (starch and sago production)
H-165	Hybridization	Industrial variety (starch and sago production)
H-226	Hybridization	Most preferred starch and sago production starch content - 28-30%
Sree Visakam	Hybrid	Table variety β-carotene (yellow flesh) rich variety (466 IU/100g.)
Sree Sahya	Multiple hybrid	Table variety, Hardy and resistant to drought, High starch content -38-41%
Sree Prakash	Clonal selection	Short duration (Crop rotation)
Sree Harsha	Triploid hybrid	Excellent cooking quality, High starch content (36-40%)
Sree Jaya	Clonal selection	Short duration (Crop rotation)
Sree Vijaya	Clonal selection	Short duration (Crop rotation)
Sree Rekha	Selection	For upland and low lands
Sree Prabha	Selection	For upland and low lands
Sree Padmanabha	-	CMD resistant cassava variety
MVD 1	Selection	Suitable for staple food and industrial uses
M_4 (Malayan 4)	-	Leading table variety in Kerala
Co 1	Clonal selection	Tolerant to CMD and scale insects.
Co 2	Clonal selection	Highly branched type, suitable for starch industry
Co 3	Clonal selection	Suitable for rainfed condition
Co (TP) 4	Clonal selection	Suitable for both rainfed and irrigated conditions.

★ Resistant to *Cercospora* leaf spot disease and tolerant to drought: Sree Prakash
★ Early maturing with good cooking quality: Sree Jaya and Sree Vijaya
★ Triploid variety of cassava: Sree Harsha

★ Multiple hybrid of cassava: Sree Sahaya
★ Tolerant to cassava mosaic virus: H-97
★ Resistant to cassava mosaic virus: CO-3

Important varieties with special features:

Non branching varieties	
Nidhi	Ideal for sandy loam soils
KMC-1	Suitable for intercropping in coconut gardens
M-4	Introduction from Malaysia, Good cooking quality
Top cross hybrids	
TCH-1 and TCH-2	Developed by CTCRI
CTCRI	Sree Visakham, H-97, H-165, H-226
TNAU	CO-1, CO-2, CO-3
KAU	Vellayani Harswa

4. YAMS

4. **Yams/Ratalu:** *Dioscorea spp.*: Dioscoreaceae: Origin: South West Asia
★ *Dioscorea* species are deciduous, perennial and dioecious vines
★ Dioscorea species commonly known as yams belongs to monocotyledons
★ Diosgenin alkaloids is obtained from yams is used for preparing contraceptic drugs
★ Yam tubers are rich source of carbohydrate content and better source of protein than other tuber crops
★ '*Fufu*' is an important product made from yam
★ Yam flour is used for human consumption as 'kokonte'
★ Yam species containing high quantity of Diosgenin is grown commercially for production of sapogenin
★ *Dioscorea deltoidea:* Diosgenin yielding and commercial used for corticosteroid production
★ Diocorea tuber is used for curing leprosy, piles and gonorrhoea
★ Type of fruit: Dehiscent, trilocular capsules

Important species:

Common name	Botanical name
Winged yam, greater yam, water yam	
Air potato, aerial yam, potato yam	

Chinese yam, lesser yam, sweet yam	*Dioscorea esculenta*
Pacific yam, hard yam	*Dioscorea nummularia*
African yam, Guinea yam, white yam	*Dioscorea rotundata*
Cushcush, Indian yam	*Dioscorea trifida*
Cinnamon yam	*D.opposita*
Yellow yam	*Dioscorea cayensis* (white flesh)

- ★ Bulbil bearing tropical yam species: *Dioscorea alata* and *Dioscorea bulbifera*
- ★ In *Dioscorea alata* no seed dormancy exists
- ★ Trailing of vines is essential practice in yam
- ★ Ethylene cholorohydrin is used for enhancing early sprouting and taking crop earlier than normal season
- ★ Dormancy period of yam: 3-4 months
- ★ Ethylene cholorohydrin (4-8%) is used for dormancy broking in yam
- ★ Ideal seed tuber weight of greater yam for optimum production: 200-250 g
- ★ Ideal seed tuber weight of white yam for optimum production: 100-125 g
- ★ Major constraint in yam breeding: Non-synchrony in flowering of male and female
- ★ Soaking of Yam in 0.1% MH causes delayed sprouting in storage
- ★ Scale Insect (*Aspidiella hartii*) is an important pest of yams in India
- ★ Anthracnose (*Colletotrichum gloeosporioides*) is the most devastating disease of greater yam 70-80% of losses

Varieties of yam:

Varieties:		
Greater Yam	**Lesser Yam**	**White Yam**
Sree Keerthi	Sree Latha	Sree Subhra
Sree Roopa	Sree Kala	Sree Priya
Sree Shilpa-1st Hybrid variety	Konkan Kanchan	Sree Dhanya- Dwarf variety, Dont require staking
Sree Karthika	-	-
Konkan Gorkand	-	-

5. ELEPHANT FOOT YAM

5. **Elephant foot yam:** *Amorphophallus paeoniifolius* (Syn. *Amorphophallus campanulatus*): Araceae: Origin: Australia
- ★ Elephant foot yam is popularly known as 'suran or jimmikand'
- ★ Perennial plant
- ★ *Amorphophallus konjac* corm flour is used for improper lipid metabolism
- ★ Economic yield of suran is obtained from corm and cormels
- ★ Smooth corm type have more acridity
- ★ Cleavage of polyembryony has also been observed in elephant foot yam
- ★ Acridity or irritant of elephant foot yam (suran) is due to calcium oxalate
- ★ Dormancy period of elephant foot yam tuber: 5-6 months
- ★ EYM have long dormancy period which can be broken by treating them with thiourea (0.1%), GA_3 and ethrel
- ★ For commercial cultivation whole or cut tubers 500-1000g are used for planting
- ★ Elephant foot yam is recommended for pile disease
- ★ **Varieties:**
  - ✦ Gajendra (Kovvur): non-acrid
  - ✦ Santragachi: non-acrid
  - ✦ Sree Padma
  - ✦ Sree Athira (Sree Padma x Am-45) (Hybrid):
    - ▪ 1st genetically improved variety of elephant foot yam no acridity or sliminess
  - ✦ Bidhan Kusum
  - ✦ Narendra Asha

6. TARO

6. **Taro:** *Colocasia esculenta*: Areaceae Origin: India to Southern Asia
- ★ Colocasia name derived from 'Egyptian word'
- ★ Taro recommended for gastric patients
- ★ Taro flour is good for baby food
- ★ Taro corms are used for fermented acidic product of '*Poi*'
- ★ Metsubre disorder of colocasia is due to calcium deficiency
- ★ **Related species:**
  - ▪ Giant taro: *Alocasia spp.* Economic [illegible] d corme
  - ▪ Tannia: *Xanthosoma spp.* Econon[illegible] corm
  - ▪ *Xanthosoma sagittifolium* variet[illegible] i (S

J. Leafy and Salad Vegetable Crops

A. Summer Leafy Vegetables

1. Amaranthus
2. Malabar Spinach

B. Winter Leafy Vegetables

3. Palak
4. Spinach
5. Fenugreek

C. Salad Vegetable Crops

6. Lettuce
7. Celery
8. Chinese Cabbage

D. Other Minor Leafy Vegetables

9. New Zealand Spinach
10. Parsley
11. Karam Sag
12. Sorrel
13. Chakwal

CPK

+ **Suitable for growing winter**: Palak, Spinach, Fenugreek, Mustard
+ **Suitable for growing summer**: Amaranth, Basella, Portulaca

A. Summer Leafy Vegetables

1. Amaranthus

1. **Poor man's leafy vegetable/Amaranthus**: *Amaranthus spp.*: Amaranthaceae: 2n=2X=32 or 34; Origin: India

★ The word *Amaranthus* is basically derived from the Greek word "Anthos" (Flower) which means everlasting or unwilting
★ Poor Man's Vegetables
★ *Amaranthus* is an important nutritional crop
★ The plant whose leaves are eaten as vegetable while seeds are eaten as cereal
★ Short duration, high edible matter/unit area

★ Valuable vegetable for malnutrition in India
★ Rich in Vitamin A (9200 IU/100g), Vitamin-C (99 mg/100g), Ca (397 mg/100g) and Mg (247 mg/100g), Fe (10 mg/100g)
★ C_4 vegetable
★ Grain Amaranth has more protein than corn and other major cereal grains
★ Amaranth is a pseudo cereal which can be used as a substitute to nutrient cereal
★ The protein (lysine) in grain amaranth ranges from 14.5% to 15.1%
★ Warm season crop
★ Primarily used as pot herb
★ Type of fruit: Glomerule
★ Fruit: Utricle
★ Susceptible to water logging condition

Features	Botanical name
Main cultivated species in India	*Amaranthus tricolor*
Short day species	*Amaranthus cruentus*
Day neutral species	*Amaranthus hypochondriacus*
Ornamental species	*Amaranthus caudatus* (Love lie bleeding)
Tetraploid species (2n=64)	*Amaranthus dubius*

★ Seed rate: 2kg/ha for direct seeding and 1kg/ha for transplanted crop
★ Amaranthus seeds are sown at a depth of about 1.0-1.5cm
★ Optimum leaf/stem ratio of amaranthus should be >1
★ Amaranth is a anemophilous (wind pollinated) vegetable crop
★ Grain type amaranth is widely grown in Gujarat and Maharashtra
★ Edible grain amaranthus species: *A. cruentatus*, *A. hypochondriacus* and *A. caudatus*
★ Amaranth grains rich source of starch: *A. hypochondriacus* (62%)
★ Grain types of *Amaranth* favour cross-pollination, while vegetables types *Blitopsis* are self-pollinated
★ Grain storage protein amaranth contains 2-4 times more [illegible] acids than normal amaranth plants
★ Chhoti Chaulai gives 6 cuttings
★ Amaranth has two anti-nutriti[illegible]
★ Harvesting starts 25 days a[illegible]

- ★ Isolation distance for seed production: 400m
- ★ Seed yield: 200kg/ha
- ★ White rust (*Albugo blitt*) is major disease of amaranthus

Varieties of amaranthus:

Varieties	Belong to group	Special features
IIHR Variety:		
Arka Samraksha	-	Pulling type
Arka Suguna	-	Pulling type , Moderately resistant white rust
Arka Varna	-	Pulling type
IARI Variety:		
Badi Chaulai	*A. tricolor*	Suitable for summer and rainy season
Chhoti Chaulai	*A. blitum*	Suitable for spring-summer season
Pusa Kiran	*A. tricolor* × *A. tristis*	Rainy season variety
Pusa Kirti	*A. tricolor*	Summer season variety
Pusa Lal Chaulai	Stem deep red colour, red dye extraction	Suitable for kitchen gardening and ornamental variety
Amt. 105	*A. tricolor*	Rich in carotene and protein
Amt. 237	*A. tricolor*	-
TNAU Varieties:		
CO-1	*A. dubius*	-
CO-2	*A. tricolor*	-
CO-3	*A. tristis*	Clipping type
CO-4	*A. hypochondriacus*	Suitable green cum grain type
CO-5	*A. blitum*	Induced tetraploid variety (Sirukeerai)
Other variety: Konkan Durangi (*A. tricolor*)		

2. Malabar Spinach

2. **Malabar spinach/Malabar night shade/Poi/Basella:** *Basella spp.* Basellaceae, Origin: South Asia (India)

- ★ Short day, succulent and climbing leafy vegetable
- ★ Vitamin A: 3250IU/100g

- ★ Basella is commonly grown in North India
  - ✦ Red Basella: *Basella rubra*: 2n=2X=44
  - ✦ Basella: *Basella alba*: 2n=2X=48
  - ✦ Heart shaped Basella: *Basella cordifolia*
- ★ Flower colour: white or pink borne
- ★ Fruit type: Fleshy perianth
- ★ Commercially propagated by seed and cuttings
- ★ Seed rate: 12-15kg/ha

B. Winter Leafy Vegetables

3. Palak

3. **Indian spinach/Spinach Beet/Palak/Beet leaf:** *Beta vulgaris* var. *bengalensis*: Amaranthaceae : 2n=2X=18: Origin: Indo-Chinese

- ★ Herbaceous annual and biennial for seed production
- ★ Rich source of vitamin-A 9770 IU, Vitamin C: 70 mg/100g and Ca: 380 mg/100g
- ★ Tolerant to saline soils
- ★ Ancestor of palak: Sea beet (*Beta vulgaris* var. *maritima*)
- ★ Palak is closely related to beet root, sugar beet (*Beta vulgaris* var. *cicla*) and swiss chard
- ★ Palak leaves contains low oxalic acid
- ★ Spinach beet is primarily used as pot herb
- ★ Palak is a cross pollinating crop
- ★ Main pollination: wind
- ★ Single fruits of palak contain 2-3seeds
- ★ Seed rate: 25-30 kg/ha for summer season and 10-15 kg/ha for winter season
- ★ Palak seed germinate after 8-10 days of sowing
- ★ Line sowing is suitable method of sowing
- ★ Palak cultivated as a biennial crop for seed production
- ★ Seed viability: 3-4 years
- ★ Fruit is seed ball or multigerm (2-3seeds/fruit)
- ★ Average leaf cuttings: 4-6
- ★ Average seed yield: 600 kg/ha
- ★ Varieties: Pusa Jyoti, Pusa Bharati, Pusa Ooty-1, HS-23

Varieties	Breeding methods	Special features
Jobner Green	Selection- spontaneous mutation Sel.5 type	Tolerant to high soil pH upto 10.5
All Green	Selection- local type	-
Punjab Green	Selection- local type	Purple pigment on stem
Punjab Selection	Selection- local type	-
Pusa Bharati	Selection- local type	Higher vitamin-C and β-carotene
Pusa Jyoti	Selection - colchicine induced polyploid (2%)	-
Pusa Harit	Sugar beet × Local Palk: Suitable for hills	Late bolting type, tolerant to alkaline soil
Pusa Palak	Swiss chard × Local Palk	Late bolting type
Banerjee's Giant	Palak × Beetroot	-
Pant Composite	Composite variety	Tolerant to *Cercospora* leaf spot

4. Spinach

4. **Spinach/Vilayati Palak**: *Spinacia oleracea:* Amaranthaceae: 2n=2X=12: Origin: Central Asia (Iran)

- ★ Herbaceous, dioecious annual
- ★ It is a member of the family Chenopodiaceae (the goosefoot family) which also contains beet sugar beet, chard and quinoa
- ★ Spinach is one of the most desirable dark green leafy vegetables
- ★ Spinach is a good source of antioxidants and has one of the highest ORAC (oxygen radical absorbance capacity) values of any vegetable
- ★ Edible part: compact rosette leaves
- ★ Lutein rich vegetable, values ranging from 10-25 mg/100g fresh weight
- ★ Rich source of vitamin-A 9300 IU, Ca: 73 mg/100g and Fe: 10.9 mg/100g
- ★ Spinach is good source of folate (prevention of neural tube defects)
- ★ Spinach is long day and cool season crop (temperate crop)
- ★ Spinach tolerates frost better than most other vegetables
- ★ Long duration crop
- ★ Sensitivity to acidity
  - ▪ Ancestor of spinach: *Spinacia tetrandra*

- ★ Original seed of spinach is prickly
- ★ Spinach is cross pollinating through wind (Anemophilous vegetable crop)
- ★ Dioecious vegetable
- ★ The sex is controlled by single pair of sex chromosomes (XY)
- ★ Spinach main sex class type: 5
- ★ Sex expression in spinach is tetramorphic
  - ▪ Sex forms: 1. Extreme male 2. Vegetative male 3. Female 4. Monoecious
- ★ True breeding plants in spinach: Monoecious
- ★ Sex reversed female (gynomonoecious)
- ★ Seed rate of spinach: 27-35 kg/ha
- ★ Spinach seed production is requires long days and a cool weather
- ★ Optimum temperature for spinach seed germination:10-15°C
- ★ **Varieties:**
  - ✦ Virginia Savoy: Prickly seeded
  - ✦ Early Smooth Leaf : Smooth seeded
- ★ Local cultivar: Desi Khara Palak, Khara Lucknowa and Banarasi or Katvi Palak
- ★ For processing preference in spinach flat leaves are used
- ★ Average cuttings: 3-4
- ★ Average seed yield: 700-100 kg/ha

Major diseases

- ▪ White rust (*Albuigo occidentalis*)
- ▪ Downy mildew (*Peronospora farinosa* f.sp. *spinaciae*): major disease
- ▪ Fusarium wilt (*Fusarium oxysporum* f.sp. *spinaciae*)

5. Fenugreek

5. **Fenugreek/Methi**: *Trigonella foenum-graceum*: Fabaceae: 2n=2X=16: Origin: Eastern Europe and Ethiopia

- ★ Fenugreek seeds yield 'Diosgenin', the precursor of steroids of sex hormones and oral contraceptives
- ✦ Common methi: *Trigonella foenum-graceum*, quick
- ✦ Champa methi/Kasuri methi: *Trigonella co* curved/sickle pod
- ✦ Both common *methi* and *kasuri*
- ✦ Fenugreek is a self-pollinatin
  - ✦ **Variety:** Pusa Early

C. Salad Vegetable Crops

Salad vegetable crops: Lettuce, celery, parsley, endive, chicory, chervil, cress and water cress

- ★ Endive: *Cichorium endive*
- ★ Chicory: *Cichorium intybus*
- ★ Chervil: *Anthriscum cerefolium*
- ★ Cress: *Lipidium sativum*
- ★ Water cress: *Nasturtium officinale*

6. Lettuce

6. **Lettuce**: *Lactuca sativa*: Asteraceae: 2n=2X=18: Origin: Eastern Mediterranean Region

- ★ Cool season crop
- ★ Leaves are commonly found in salad mixtures and sandwiches
- ★ Lutein rich vegetable
- ★ Sensitive to highly acidic soils
- ★ Vitamin A: 1650 IU/100g and Ca: 50 mg/100g
- ★ Shallow rooted crop
- ★ Lettuce have 4 salad types
- ★ *Lactuca virosa*: extracted dried latex (Lactucarium): is used to make a sleep-inducing medicine
- ★ Total morphological types recognised in lettuce: 6 crisphead, butterhead, romaine, leaf, stem and Latin
  - ✦ Progenitor of cultivated Lettuce: *Lactuca serricola* : Resistant to insect, drought, β-carotene and lutein
  - ✦ Indian lettuce: *Lactuca indica*
  - ✦ Wild/Prickly lettuce: *Lactuca scariola*
  - ✦ *Lactuca virosa*: Resistant to downy mildew and lettuce mosaic virus
  - ✦
- ★ Four principal types of lettuce in the world except China: crisphead, butterhead, romaine, and leaf
- ★ Crisphead is the leading type in the world
- ★ Stem lettuce, the major lettuce type produced in China
- ★ Lettuce seed have thermo-dormancy
- ★ Highly self-pollinated crop
- ★ Mulching is most essential operation in lettuce cultivation

- ★ Seed rate: 400-500g/ha
- ★ Optimum temperature for lettuce seed germination: 24-25°C
- ★ Lettuce seed dormancy breaking temperature: 4-6°C for 3-5 days
- ★ Recommended CO_2 in lettuce cultivation: 1000-1500ppm
- ★ Lettuce seeds germinate 4-5 days
- ★ Type of inflorescence: Capitulum
- ★ Type of fruit: Achene

Varieties:

- ★ Most common grown lettuce: Crisp head lettuce
  - ✦ Punjab Lettuce No.1 is non-heading type cultivar of Lettuce
  - ✦ Leaf type lettuce: Slobolt, Chinese Yellow
  - ✦ Butter head lettuce: White Boston, Big Boston
  - ✦ Tinged brownish colour variety: Iceberg
  - ✦ Stem type lettuce: Celtuce
  - ✦ Great Lakes (wholly green colour): Crisp head cultivar and Resistant to tip burn
  - ✦ Butter head cultivars: Reskia Wonder, Van Voorfing and Mary King
- ★ Seed yield:
  - ✦ Leaf type: 500-600kg/ha
  - ✦ Head type: 100-125kg/ha

Pest and Diseases:

- ★ Lettuce mosaic virus disease is seed borne and aphids transmission
- ★ Downy mildew (*Bremia lactuace*) is a most serious disease
- ★ Botrytis rot: *Botrytis cinerea*: Serious disease in green type
- ★ *Big vein of Lettuce* is due to Virus, which is transmitted by *Olpidium brassicae* fungus
- ★ Most important disease in head lettuce: Slimy Soft rot
- ★ Post harvest disease: Botrytis rot and soft rot (*Erwinia carotovora*

Physiological disorders:

- ★ Tip burn is a physiological disorder of … deficiency of Ca, Mn and Boron … ontogenic age of plant
- ★ Russet spotting is the disorder …

7. **Celery**: *Apium graveolens*:

- ★ Biennial crop and see …

- ★ Shallow rooted crop and moisture loving plant
- ★ Sensitive to water logging and salinity
- ★ Leaves contain glucosides 'apiin'
- ★ Edible portion: fleshy petiole
- ★ It ranks 2nd importance amongst salad crops
- ★ Seeds are used as condiments and medicinal preparation
- ★ Seeds contains 2-3% of volatile oil
- ★ Botanical varieties:
  - ✦ Celeriac: *Apium graveolens* var. *rapaceum* (Turnip rooted celery): Edible part: Swollen roots
  - ✦ *Apium graveolens* var. *secalinum*: Leafy type
  - ✦ *Apium graveolens* var. *dulce*: Blanched celery
- ★ IARI recommended variety: Standard Bearer and Wright Globe Giant
- ★ Self blanching variety: Florida Golden and Golden
- ★ Green leaf variety: Wright Grove Giant, Fort Hook Emperor and Standard Bearer
- ★ Emperor is variety of celery
- ★ Mainly propagated by seed (Slow germinated crop)
  - ✦ Seed rate: 150-250g/ha
- ★ Seed shattering is a major problem
- ★ Suitable temperature for celery cultivation: 15-21°C
- ★ Celery crop bolts when temperature fall below 15°C
- ★ High temperature causes bolting and bitterness in celery leaves
- ★ BA @ 10ppm enhance shelf life
- ★ Wrapping of leaf petioles with dark brown paper around them in celery in known as blanching
- ★ Blanching is done to make the crop crisp, reduce acrid flavour, increase good flavour and tenderness
- ★ Celery absorb foreign flavour during storage
- ★ Celery seeds produced only in hills (Biennial crop)

Physiological disorders:

Physiological disorders	Causes
Black heart	Calcium deficiency
Cracked stem	Boron deficiency
Pencil strip	Excess of phosphorus
Chlorosis	Mg deficiency

8. Chinese Cabbage

8. **Chinese cabbage**: *Brassica* campestris: 2n=2X=20: Brassicaceae: Origin: China
- ★ Originated from hybridization between *Turnip* (*B. campestris* ssp. *rapifera*) and *Pak-Choi* (*B.campestris* ssp. *chinensis*)
  - ✦ Pe-tsai: *Brassica pekinensis*: 2n=2X=20
  - ✦ Pak-choi: *Brassica chinensis*: 2n=2X=20
- ★ Both *Pe-tsai* and *pak-choi* are cross pollinating annuals with presence of Sporophytic SI
- ★ Chinese cabbage is cool season crop
- ★ Chinese cabbage is classified as 4 types
- ★ Sensitivity to high temperature
- ★ Seed rate: 500g for transplanting and 2.5kg/ha for direct seeding
- ★ Most commonly following method: Direct seeding
- ★ Thinning (5-6 leaf stage) is very important operation in Chinese cabbage
- ★ Low O_2 (2%) and low CO_2 (2%) improves shelf life of Chinese cabbage

Varieties:
- ♣ **PAU**-Chinese Sarson No.1: Non heading type and field resistance to *Alternaria* leaf spot
- ♣ **New variety**: Himachal Pradesh Krishi Vishvavidyalaya, Palampur: Palampur Green
- ★ Mulching is recommended in Chinese cabbage

9. Other Minor Leafy Vegetables

New Zealand Spinach: *Tetragonia tetragonoides*: Aizoaceae: 2n=32: Origin: New Zealand
- ✦ Warm season crop and moderately tolerant to frost

Other winter leafy vegetables:
- ▪ Parsley: *Petroselinum hortense*: **Variety**: Hamburg: Rich in Vitamin C: 90mg/100g
- ▪ Karam Sag: *Brassica oleracea* var. *acephala*: Cruciferae
- ▪ Sorrel: *Rumex vesicarius:* Polygonaceae: Commonly known as *Khatta palak*
- ▪ Chakwal: *Atripex hortensis*: Chenopodiaceae: Commonly known as Orach or Mountain spinach, strong flavour than spinach

K. Perennial Vegetable Crops

1. Asparagus	2. Drumstick
3. Chekkurmanis	4. Bread fruit
5. Globe artichoke	6. Rhubarb
7. Curry leaf	8. Ceylon spinach
9. Jerusalem artichoke	10. Horse radish

- **Perennial vegetables:** Asparagus, rhubarb, artichoke and sea kale (*Crambe maritima*)

1. Asparagus

1. **Asparagus:** *Asparagus officinalis*: Liliaceae: 2n=2X=20: Origin: Temperate Europe and Asia
   - ★ Herbaceous perennial, dioecious herb
   - ★ The sex ratio 1:1 (male: female)
   - ★ Edible part: Soft tender shoot of asparagus is known as 'spears'
   - ★ Tender shoots of asparagus contain a white crystalline substance is called 'asparagine'
   - ★ Asparagine is used in diuretic in cardiac dropsy and chronic gout
   - ★ Closely related species of asparagus: Smilax (Ornamental asparagus)
   - ★ Garden asparagus belongs to *Asparagus officinalis* var. *altilis*
   - ★ Flower colour: Whitish green
   - ★ Asparagus is propagated by rhizome (crown)
   - ★ Polyembryony observed in asparagus
   - ★ Seed rate: 3-4 kg/ha
   - ★ Asparagus male plants (*MM*) are higher yielding and more live than female plants (*mm*)
   - ★ Application of common salt is beneficial in the cultivation of asparagus
   - ★ White or light green varieties are used in processing
   - ★ Blanched (whitish) spears are preferred for canning
   - ★ Blanching is practised to blanch the young spears and get white asparagus for canning
   - ★ Green spears have more nutritive value than white asparagus (blanched spears)
   - ★ Green asparagus is used for fresh market
   - ★ Green varieties are more popular and produced mainly for fresh market
   - ★ Fusarium stem, crown and root rot caused by the soil-borne *Fusarium* is most serious disease

Varieties:

- ★ Recommended variety of IARI: Perfection

Perfection	Mary Washington	New Jersey Improved
Book's special	Martha Washington	Jersey Queen

2. Drumstick

2. **Moringa/Horse radish tree/Radish tree/West Indian bean:** *Moringa oleifera*: Moringaceae: 2n=2X=28: Origin: North West India
   - ★ Deciduous, tropical plant
   - ★ Multipurpose tree
   - ★ Main edible part: immature fruits and leaves
   - ★ Tamil Nadu leading in area and production in India
   - ★ Monogeneric family
   - ★ Seeds contain an oil is called "behen/ben oil"
   - ★ Seed oil percentage: 38-40%
   - ★ Drumstick oil cake is used as organic substitute for water purifying chemicals such as aluminium sulphate (alum)
   - ★ Oil used for illumination, soap industry and highly priced for lubricating watches and computers
   - ★ Highly cross pollinated crop due to hetermorphism and is entomophilous, honeybees being pollinators
   - ★ Flower colour: white or creamy white
   - ★ Perennial types of drumstick is propagated by limb cuttings
   - ★ Annual types of drumstick is propagated by seeds (625g/ha)
   - ★ Hairy caterpillar causes defoliation in drumstick, which is controlled by spraying with fish oil resin soap
   - ★ Export variety of moringa: Valayapatti

Varieties of moringa:

Varieties		
Jaffna	Valayapatti Murungai (export variety)	Moolanoor Murungai
PKM-1-Annual type of moringa	Chemmurungai	Palmurungai
PKM-2- MP-31× MP-28	Kattu Murungai	
KM-1(Kudumianmalai-1)	Kodaikal Murungai	

Purpose:

PKM-1	Propagation by seed	Annual type
PKM-2	Propagation by seed	Annual type, extra long fruits, suitable for Kitchen garden
Konkan Ruchira		Best quality

3. Chekkurmanis

3. **Multivitamin and multimineral packed leafy vegetable/Thavara Murungai:** *Sauropus androgynus*: Euphorbiaceae: Origin: Indo-Burma
   - ★ Perennial small shrubby leafy vegetable
   - ★ Chekkurmanis leaves are very rich in protein (6.8-7.4%) than amaranthus (3.2%)
   - ★ Vitamin-A: 9670IU and Vitamin-C: 247mg/100g
   - ★ Edible part of chekkurmanis: Leaves and tender shoot- used as leafy vegetable or as salad
   - ★ Highly cross pollinated is due to protogyny and entomophilous in nature
   - ★ Propagated by herbaceous stem cuttings
   - ★ Cuttings Requirement/ha: 1 lakh cuttings

4. Bread fruit

4. **Bread Fruit:** *Artocarpus altilis*: Moraceae: 2n=2X=56: Origin: Malaysia
   - ★ Seedless bread fruit contain high amount of carbhohydrate (27.98%)
   - ★ Breadfruit is monoecious but tree
   - ★ Dicolinous (bearing male and female inflorescence on specialised laterals)
   - ★ Seedlessness in breadfruit is due to stimulative parthenocarpy
   - ★ **Variety**: Yellow Heart
   - ★ Breadfruit seeds are recalcitrant
   - ★ Seedless breadfruit is propagated by root cuttings, air layering of root suckers
   - ★ Horizontal planting of root suckers is best planting method (90% success)
   - ★ Soft rot (*Rhizopus artocarpi*) is most common fungus leading to rotting and fruit drop

5. Globe Artichoke

5. **Globe Artichoke:** *Cynara scolymus*: Asteraceae: 2n=2X=34: Origin: Mediterranean region
   - ★ Herbaceous perennial herb cultivated as annual crop
   - ★ Optimum temperature for globe artichoke: 12-18°C
   - ★ Artichorous or thistle like plant
   - ★ Edible part: Edible young heads or buds (*Capitulum*)
   - ★ Flower heads are useful in the dietary of diabetics
     - ♣ Progenitor of Globe artichoke: Cardoon (*Cynara cardunculus*)
   - ★ Cross pollinated crop
   - ★ Main pollinators: Insects
   - ★ Commercially propagated by suckers/offshoots/division from old crowns

6. Rhubarb

6. **Rhubarb**: *Rheum rhaponticum*: Polygonaceae: 2n = 4X=44: Origin: Siberia
   - ★ Rhubarb is a cold resistant plant
   - ★ Economic part: Large thick leafstalk or petiole
   - ★ Rhubarb is propagated by the division of crowns
   - ★ Production of rhubarb stalks during the winter is called 'forcing of rhubarb'
   - ★ Type of inflorescence: Panicles, white flower, protandrous in nature
   - ★ **Varieties:** Victoria and Linnaeus
   - ★ **New varieties:** Red stalk: Mc Donald, Ruby Valentine, Sun Rise, Strawberry and Cherry Red
   - ★ Rhubarb is most suceptible to root knot nematode (*Meloidogyne sp.*)

7. Curry Leaf

7. **Curry leaf:** *Murraya koenigi*: Rutaceae: 2n=2X=18: Origin: India (*Tarai* tract of Uttar Pradesh)
   - ★ Perennial aromatic tree cum spice crop of India
   - ★ Backyard crop in Southern India
   - ★ A volatile oil, a crystalline glucosides 'leaves-ksenign' and 'flowers-murayin'
     - ✦ Related species: *Murraya exotica*- Ornamental shrub: Origin-India
   - ★ Flowers: Terminal corymbose cymes
   - ★ Polyembryony in nature
   - ★ Self pollinated crop
   - ★ Fruits contain 2 seeds/fruit
   - ★ Propagation by seeds

Varieties	S
DWD-1 (Suwasini)	
DWD-2	
Senkambu	

8. Ceylon spinach

8. **Ceylon Spinach/Water Leaf**: *Talinum triangulare*: Portuaceae: 2n = 24, 48, 72: Origin: Brazil
   - ★ Soft mucilaginous leafy vegetables
   - ★ Shade loving crop
   - ★ Propagated by seeds or herbaceous cuttings

9. Jerusalem Artichoke

9. **Jerusalem Artichoke**: *Helianthus tuberosus*: Asteraceae: 2n=2X=102: Origin: North America
   - ★ Edible part: Tubers
   - ★ Tubers contains insulin used for diabetics

10. Horse Radish

10. **Horse radish**: *Armoracia rusticana*
   - ★ Perennial crop
   - ★ Edible part: Roots
   - ★ Propagation by crowns
   - ★ Pungency of horse radish is due to isothiocyanate

CPK

L. Vegetable important Scientist

- ★ World Vegetable Centre established at Taiwan in 1971

Solanaceous vegetables:

- ★ Bt brinjal developed for resistant to shoot and fruit borer (gene: Cry 1 Ac)
- ★ Phomopsis blight resistance governed by polygenic recessive
- ★ Highly polymorphic species of tomato *Solanum peruvianum*
- ★ Long style formation can be induced by foliar application of GA3 @100-200 ppm
- ★ Classification of tomato into two sub species was done by Bailey (1949)
- ★ *Solanum lycopersicum* (Recent classification) given by: Peralta and Spooner, 2006
- ★ Father of tomato: C.M. Rick
- ★ Stamenless mutant of tomato sensitive to temperature
- ★ Chilli fruit setting percentage ranged between 40-50%
- ★ Potato is a segmented allopolyploid-(Autotetraploid)
- ★ Seed Plot Technique (SPT) was developed by Dr.Pushkarnath
- ★ True Potato Seed (TPS) concept commercialised in India by Dr. S. Ramanujam

Tomato:

- ★ Miller coined the name of *Lycopersicon esculentum* to cultivated tomato
- ★ Muller, 1940 divided genus *Lycopersicon* into sub-genus *Eulycopersicon* and *Eriopersicon*
- ★ First tomato linkage map published by Hedrick and Booth (1907)
- ★ Tomato high density map was constructed by Tanksley (1992)
- ★ ILs (Introgression libraries) concept is first developed by Eshed and Zamir (1994) in wild species *S. pennelli*
- ★ AB-QTL (Advanced backcross QTL analysis) was proposed by Tanksley and Nelson (1996)
- ★ International Solanaceae Genome project (SOL), Cornell University, USA
- ★ Tomato genetic resource centre (TGRC), University of California, Davis, USA
- ★ First machine-harvestable cultivar developed by G.C Hanna
- ★ First tomato resistant cultivar: Pan American
- ★ Father of tomato breeding: Dr.C.M. Rick, University of California, USA
- ★ Father of tomato: Dr. Goutham Kallo
- ★ In India the book entitled "Tomato" was written by Dr.G.Kallo in 1986

Brinjal:

- ★ The first report of heterosis proposed by Kal
- ★ The first molecular map published by Nu

★ First male sterility was reported by Jasmin (1954)

★ First functional male sterility line: *UGA1-MS* (Cultivar- Florida high bush). Pathak & Jaworski 1989

★ In 1939, Thomas and Krishnaswamy was first reported little leaf disease of brinjal in India

★ Nagai and Kida first reported hybrid vigour in Brinjal in 1926

Chilli:

★ Taxonomic characters of five cultivated species given by: Greenleaf (1986)

★ The extensive cross ability studies done by Smith and Heiser (1957)

★ Extensive studies on chilli male sterility: Shifriss (1997)

★ Hortjcultural Classification of pepper varieties was given by Dr. P.G. Smith, University of California, Davis

★ According to Smith Horticultural classification: 13 cultivars group

★ CMS in pepper 1st discovered by Peterson in *C. annuum* (PI164835) from India

★ The male sterile (S-) cytoplasm has so far been most commonly utilized for commercial hybrid development in South Korea

★ Sterile cytoplasm in all capsicum CMS lines originated from 'Seungchon' except for CCA7231, which originated from Suwon

Okra:

★ Okra originated from India: Masters (1845), Hindustan origin: Zeven and Zhukovsky (1975)

★ Okra is a polyploidy crop suggested by Charrier, 1984.

★ Taxonomic revision of okra is done by Borssum Waalkes,1966.

★ International okra workshop held at NBPGR, New Delhi, 1990

★ Genus *Abelmoschus* was 1st established by Medikus in 1787

★ Dr. Harbhajan Singh initiated systematic research work on improvement of okra in India

★ Ratooning okra varieties: Pusa A-4 and Arka Abhay

★ New okra species reported in india: *Abelmoschus enbeepeegearense*

Cucurbits:

★ The term Cucurbits coined by Dr. Bailey

★ The trend of evolution in *Luffa* as given by Dutt and Roy (1971)

★ Kihara (1951)-reported production of seedless Watermelon fruits through triploidy

★ Peterson and Weigle (1958) advocated use of gynomonoecious lines for production of hybrid seeds in Cucumber

★ According to Jeffrey (1983) 117 genera and 825 spp of Cucurbitaceae

★ According to Chakravarty (1982) 36 genera and 100 spp. of Cucurbitaceae

★ Jaffrey (1980) classified *Cucumis* into two sub genera

★ King of Gourd-Pointed Gourd

★ Leading producer of gherkin in India: KN > TN

★ Economic sex ratio in cucurbits 15:1

★ Primitive sex form of cucurbits: Hermaphrodite

★ Advanced sex form: Monoecious

★ Highly unstable and not breeding true: Trimonoecious (andro-gynomonoecious)

★ For long distance market muskmelon harvested at ½ slip stage

★ Watermelon parthenocarpy- stimulative parthenocarpy

★ Fusarium wilt resistance in watermelon developed by W.A Orton (1911), Variety: Conqueror

★ Min. standard TSS for musk melon 10%

Musk melon:

★ Cucumis entire genus classified in to 2 sub genera Jaffrey *et al* 1980

★ First recorded attempt to cross musk melon with other species: Naudin (1859)

★ First recessive male sterile line gene *ms-1* in muskmelon reported by Bohn and Whitaker (1949)

★ First F_1 hybrid (Punjab Hybrid-1, male sterility based) in muskmelon released at national level in 1984.

★ First gynoecious line of musk melon developed by Peterson, 1983.

★ PMR 45 resistant to powdery mildew was bred in 1930, California by Jagger and Scott, 1937.

★ Melon is a semi-allogamous species

★ One single fruit will produces 300 to 500 seeds

★ New species *Cucumis* × *hytivus* was proposed by Chen and Kirkbride (2000)

★ Breeding for powdery mildew resistant cultivar: Cantaloupe-45 or PMR-45 by I.C. Jagger and G.W. Scott, 1937

★ Powdery mildew resistance governed by single dominant gene

★ International Cucurbit Genomics Initiative (ICuGI)

★ Cucurbit Genomics Database, Institute of Vegetables and Flowers, Beijing, China

Cucumber:

★ First gynoecious line: M.SU.713-5 (Shogoin (P.I.220860) × Wisconsin SMR 18) developed by C.E. Peterson, 1960.

★ Tropical true gynoecious lines developed by T.A. More and Sheshadari (1980)

★ Parthenocarpy in cucumber is controlled by incomplete dominant gene or multiple genes

Watermelon:

★ First triploid watermelon developed by Hitoshi Kihara, 1947.

★ Colchicines induces the polyploidy

★ Popular tetraploid cultivar:

★ Improvement of small water melon done by J.M.Crall, 1986, USA Varieties: Minilee, Mickylee

★ First true mini watermelon cultivar New Hampshire Midget was developed by A.F. Yeager, 1951.

★ Personal size seedless watermelon developed in 21st century, variety name: Pure Heart

Cruciferaceae:

★ Schulz (1919) considered *Brassica cretica* probable ancestor of cauliflower

★ Hegi (1919) *Brassica oleracea var. sylvestris* is probable ancestor of all cole crops

★ Nieuwhof (1959) was proposed Family Selection method for Cabbage

★ The book cole crops written by-Nieuwhof (1969)

★ Origin of *Brassica alboglabra* (Chinese kale): China

★ Progenitor of Chinese kale: *Brassica cretica* subspp. *nivea*

★ Ancestral Broccoli: *Brassica cretica* ssp. *nivea*

★ Kalamsag closely associated with *brassica alboglabra*

★ Hakuran vegetable developed from Japan

★ Cauliflower introduced to India in 1822, Saharanpur, UP

Cole crops

♣ S allele collection started at 1968

♣ S allele collection materials are collected and maintained at Horticultural Research International, Wellesbourne, Warwick, UK

♣ The term self incompatibility coined by stout 1917

♣ Brassica U's triangle concept given by "Nagaharu U", 1935.

♣ *Palam* series of varieties developed by Dr. Pritam Kalia, IARI, New Delhi

♣ Father of cole crops in India: Dr. Pritam Kalia

Root crops:

★ Banga (1976): Radish classification of cultivated varieties

★ Ogura (1968) was 1st reported Cytoplasmic male sterility in Radish

★ New carrot var.-Pusa Asita (black) Pusa Rudhira-tropical red carrot, Pusa Vristi tropical carrot

★ Pusa Nayanjyoti first CMS based F_1 hybrid released in india

★ Classification of turnip cultivars based on root and top characters: Shoemaker (1949)

Carrot

★ The Petaloid cytoplasm known as "Cornell Petaloid" was first discovered by Munger in 19

★ Inheritance of Petaloid male sterility Dominant alleles of each of the three duplicate nucle genes (*Ms1, Ms2, and Ms3*)

★ Another source of Petaloid CMS "Wisconsin Petaloid" discovered by Morelock et al., 1995

★ Recent Petaloid type is "Guelph Petaloid" was identified in Ontario Canada Wolyn and Chahal (1998)

★ Brown anther male sterility is originated from cultivar Tender sweet Welch and Grimball, 1947.

★ Brown anther CMS was the first type used for developing hybrid carrot varieties

★ Inheritance of brown-anther sterility was due to a homozygous recessive locus *Ms3* or a dominant allele for *Ms4*. (Hansche and Gabelman,1963; Banga et al. 1964)

★ Gummifer male sterility is derived from wild species *D.gummifer* (Single recessive gene), T. Nothangel, 1992

★ Carrot fly resistant source: *D. capillifolius*

★ First carrot fly resistant variety: Flyaway (1993)

Leguminous crops:

★ Optimum temperature for germination of pea seed: 22°C

★ Garden Pea: Palam Priya powdery mildew resistant variety

★ Verdcourt (1970) classified five sub species of cowpea

★ Cross pollinated spp of French bean *Phaseolous coccineus*

★ Guar cum (galacomannan) obtained from cluster bean seed

★ Bean common mosaic (BCMV) transmitted by aphids and seed

★ Pusa Komal: Photoinsensitive var. of cowpea

★ Pusa Paravati (x ray mutant of wax pod)variety of French bean developed by H.S. Gill

Garden peas

★ Two pea geneticist done great work on germplasm collection: Herbert Lamprecht, Stig B

★ *Pisum* genetics newsletter published from John Innes Centre, England, 1994

Leafy vegetables:

★ Asparagus-Day neutral plant

★ Vacuum cooling –leafy vegetables

★ Co-5 tetraploid var. of amaranthus (A

Lettuce

Jagger 1922

★ *Allium karataviense:* For growing on rock garden
★ Highest physiological efficiency: Onion
★ Desirable drying ratio for dehydration in onion 6:1 but in India cultivars have 10:1
★ Downy mildew onion resistant species: *Allium roylei*
★ Onion has 6 stamens
★ Onion bulb shape governed by multiple genes
★ Onion normally long day plant
★ Maturity indices of onion: Neck fall (25-50 %)
★ Onion is richest source of Vanadium
★ Leek (Autotetraploid or Allotetraploid) and Kurrat are inter fertile
★ Leek closely linked to wild *Allium ampheloprasum*

Onion:

★ The most and recent systematic survey of crossabiltiy in cultivated *Alliums* reported by Raamdonk *et al.*, 2003
★ Commercially utilized taxonomic classification: Hanelt (1990)
★ Onion male sterility 1st discovered in 1925
★ First CMS source discovered by Jones and Emsweller (1943) in the variety Italian Red 13-33 (CMS-S)
★ The inheritance of CMS S and interaction between cytoplasm and mitochondria was characterized by Jones and Clarke (1943)
★ 'T' cytoplasm was discovered by Berninger (1965) in the French cultivar "Jaune paille des Vertus"
★ 'T' cytoplasm inheritance is characterized by Schweisguth (1973)
★ Onion chloroplast genome inherited through maternal inheritance
★ Mitochondrial gene mutations leads to male sterility in plants
★ Multiplasms: Term coined by Grogen (1971)
★ Production hybrids that containing a blended of several kinds of male sterile cytoplasms
★ The series of shallot monosomic addition lines developed by Shigyo *et al.*, 1996
★ Gene pool concept given by Harlan and de Wet (1971)

M. Important Terms and Scientists

Basic genetics:

1. Cell organelles

★ Cell wall present only in plants
★ Cell to cell connection channel: Plasmotesmata
★ Plasmalemma/Ectoplast: Semi-permeable in nature
★ Protoplasm: Cytoplasm+nucleus
★ Endoplasmic reticulatum: Smooth ER: Site for lipid synthesis
★ Rough ER: Site for protein synthesis
★ Ribosome: Smallest cell organelle: 70S RNA but in plant 80S RNA
★ Ribosome: Site of protein synthesis
★ Golgi bodies: Packaging parts of cell
★ Lysosomes: Suicidal bags of cell: Autolysis of cell
★ Spherosome: Lipid storage
★ Peroxisomes: Role of photorespiration in C_3 plants
★ Glyoxsomes: Fat metabolism
★ Centriole: Organisation of spindle fibres and chromosomes
★ Mitochondria: Power house of cell: Responsible for respiration, Semi-autonomous organelle
★ Chloroplast: Site of photosynthesis
★ Grana: Light reaction
★ Stroma: Dark reaction
★ Nucleus: Ribosome synthesis- Storage of DNA- Largest cell organelle in the cell

2. Cell division:

Mitosis: Occurs in somatic cells

♣ Interphase: G1- protein and RNA synthesis
♣ S phase: DNA synthesis
♣ Prophase: Chromosomes are visible
♣ Metaphase: Best stage for chromosomal study

Meiosis:

♣ Meiosis I: Reductional division
♣ Meiosis II: Equational division (Similar to mitosis)
♣ Leptotene: Synthesis of RNA

- Zygotene: Development synaptonemal complex, Occurrence of synapsis (Pairing of homologous chromosomes)
- Pachytene: Formation of bivalents, tetrad stage, occurrence of crossing over (Chiasmata)
- Diplotene: Visibly observation of crossing over

Ratio:

	F2
Monohybrid ratio	Phenotypic: 3:1 and Genotypic:1:2:1
Test cross (Single gene)	1:1
Dihybrid ratio	Phenotypic: 9:3:3:1
Test cross (Two genes)	1:1:1:1
Trihybrid ratio	27:9:9:3:9:3:3:1

Type of epistasis:

Gene interaction	F2 ratio
Duplicate recessive or complementary gene action	9:7
Duplicate dominant epistasis/Duplicate gene action	15:1
Recessive epistasis/supplementary gene action	9:3:4
Dominant epistasis/inhibitory gene action	12:3:1
Dominant and recessive interaction, typical epistasis	13:3
Duplicate genes with cumulative effect (Polymeric gene interaction)	9:6:1

Basic genetics:

- ★ Theory of evolution: Charles Darwin
- ★ The term "Genetics" and "Epistasis"was coined by Bateson
- ★ Father of genetics: Johann Gregor Mendel
- ★ The term "Heteromorphic" was coined by Fisher and Mather
- ★ *"Gene, Genotype, Phenotype, Pure Line, Population"*-coined by Johannsen (1909)
- ★ "Oligogenic, Polygenic, Potential Variability, Scaling Test, Disruptive Selection, Free Variability"- coined by Mather
- ★ The term "Mitosis" was coined by Flemming (1882)
- ★ The term "chromosome" was coined by Waldeyer (1888)
- ★ The Double Helical Structure of DNA was proposed by Wateson and Crick (1953)

- ★ S. Benzer (1957) coined the word "Cistron", "Recon", "Muton"
- ★ The one gene one enzyeme Hypothesis was given by Beadle and Tatum
- ★ Transposgenes or jumping genes: Barbara Mc Clintock
- ★ The Operon hypothesis was proposed by Jacob and Monod
- ★ The Operon Concept was developed in *E.coli*
- ★ The concept of Gene for Gene Hypothesis was developed by Flor (1956)
- ★ The concept of Core Collection was given by Frankel (1984)

Quantitative genetics:

- ★ The term *"Diallel"* coined by Yates (1947)
- ★ Partial Diallel, *Line x Tester* Cross: Kempthorne (1957)
- ★ Quadriallel: Rawlings and Cokerham (1962)
- ★ Triallel Cross: Kearsey and Jinks (1968)
- ★ Test cross: Bridges (1934)
- ★ Concept of D^2 statistics was originally developed by P.C. Mahalanobis (1928)
- ★ Concept of Generation Mean Analysis was developed by Hayman and Mather and Jinks (1958)
- ★ Concept of Metroglyph analysis was developed by Anderson (1957)
- ★ Concept of Path Analysis was originally developed by Sewall Wright (1921)
- ★ Graphical Approach of Diallel Analysis was developed by Hayman (1954)
- ★ Numerical Approach of Diallel Analysis was developed by Griffing (1956)
- ★ Joint Scaling Test was devised by Cavalli (1952)

Breeding methods for vegetable crops:

Self-incompatibility:

- ★ The term "Self-incompatibility" was originally coined by Stout (1917)
- ★ Koelreuter, first reported self-incompatibility in *Verbascum phoeniceum*
- ★ Gametophytic System of SI was first discovered by East and Mangelsdorf (1925) in *Nicotiana sanderae*
- ★ Sporophytic System of SI was first discovered by Hughes and Babcock (1950) in *Crepis foetida* and Gerstel in *Parthenium argentatum*
- ★ Incompatibility is not successful in Chinese Cabbage, which generally [illegible] high temperature
- ★ Early cauliflower varieties are highly self-compatible and [illegible] incompatibility whereas later varieties are high level of self-incompatibility
- ★ SI mechanism is weak in Cauliflower whereas [illegible]
- ★ Brussels Sprouts possess weak self-incompat[illegible]

★ *Broccoli and Kohlrabi have an effective system of SI whereas Calabrese, moderate degree of SI*

Male sterility:

★ Koelreuter (1763) first reported male sterility in flowering plants

★ Cytoplasmic genetic male sterility (CGMS) was first discovered by Jones and Davis (1944) in Onion

★ Gene-cytoplasmic male sterility (GCMS) was 1st reported by Jones and Emsweller in Onion var. *Italian Red.*

★ GCMS: .Onion, Carrot, Radish

★ Japan developed the first F_1 hybrid of celery by using CMS: Green Giant (1982), Takii Seed Company

★ Watts suggested the use of glabrous leaf marker and male sterile controlled by single recessive gene for the hybrid seed production of watermelon

★ In cucumber, male sterility is associated with glabrous seedlings and determinate growth habit

★ Glabrous seedling marker used in muskmelon

★ Mohr *et al.,* (1955): Non-lobed leaf morphological character

Selection:

★ Pure line selection (PS) method was first employed by Johannsen to improve seed weight of French Bean

★ Pure line Theory was developed by Johannsen (1903) in French Bean var. Princess

★ The Progeny Test (Vilmorin Principle) was developed by Louis de Vilmorin

★ Jensen proposed the idea of Multiline in 1952 for use in Cereals

★ Stratified Mass Selection was proposed by C.O.Gardener, 1961.

★ Mass Pedigree Method name given by S.S.Rajan.

★ Grid Method of Mass Selection was suggested by Gardener1962.

★ Mass Pedigree Method was proposed by Harrington, 1937.

★ Single Seed Descent (SSD) Method: Concept was given by C.A. Brim 1966.

★ Single Seed Descent method was suggested by Goulden,1939.

★ The concept of Bulk Breeding Method was developed by Nilsson Ehle, 1908.

★ The concept of Parallel Variation (law of homologous series of variation) was developed by Vavilov, 1951.

★ Double back cross method was adopted in tomato

★ The "Recurrent Selection" was coined by Hull (1945)

★ The procedure of Recurrent Selection was described by Jenkins (1940)

★ The initial idea about Recurrent Selection was independently given by Hayes and Garber (1919) and East and Jones (1920)

★ Recurrent Selection for SCA was proposed by F.H.Hull (1945)

★ Reciprocal Recurrent Selection proposed by R.E.Comstock, H.F.Robinson and P.H. Harvey, 1949.

★ Recurrent selection for SCA proposed by Hull

★ Recurrent selection for GCA was first suggested by Jenkins

Heterosis:

★ Epistasis is a term originally proposed by Bateson, 1909.

★ The term "Heterosis" coined by G.H. Shull, 1909.

★ The term "Heterobeltiosis" was coined by Fonseca and Patterson

★ The term "Useful Heterosis" was used by Meredith and Bridge, 1972.

★ The term "Over dominance" was coined by Hull, 1945 in Maize

★ Complementary hypothesis was proposed by Bateman, 1952.

★ Over dominance theory was proposed by G.H. Shull and E.M. East (1908)

★ Dominance Theory was proposed by C.B. Davenport (1908), A.B. Bruce, F. Keeble and C. Pellew (1910)

★ Shull was the first to produce a single cross hybrid in maize

★ Single Cross: G.H.Shull, Double Cross: D.F.Jones

★ Top cross method was suggested by Davis (1927)

★ Double cross was proposed in Cabbage and Marrow Stem Kale for producing hybrid seeds

★ Triple cross suggested to produce large quantity of seeds in Kale

★ In cole crops particularly in Kale, triple cross hybrid was suggested by Thompson

★ The procedure for producing single, three way, double cross hybrids using self-incompatibility in Chinese Cabbage was described Tsujimoto and Minami

★ Heterosis in Tomato was first reported in 1907, Hedrick and Booth

★ The first report of Hybrid vigour in Chilli(*Capsicum annum*) was reported by Deshpande,1933.

★ 1st hybrid vigour in brinjal was reported by Nagai and Kida, 1926.

★ Hayes and Jones, 1916 were the first to observe Heterosis in Cucumber

Interspecific hybridization:

★ Thomas Fairchild (1717) developed 1st interspecific hybrid between Sweet William and Carnation

★ Rimpu (1890) in Swede made 1st intergeneric hybridization between Bread Wheat and Rye

★ Karpechenko (1927) developed 1st intergeneric hybrid between Radish and Cabbage in Russia

★ *Cucubitamoschata* × *C.maxima*- easily crossable

★ *Capsicum annum* × *C.frutescens* -easily crossable

- *Solanum indicum* × *S.melongena* -easily crossable
- *Incongruity: All barriers in crosses*

Special breeding techniques:

- Selfing and Massing suggested by Jones and Mann (1963)
- Selfing and Massing scheme for the improvement of Onion (*Allium cepa*)
- The concept of "Biparental Mating" was originally developed by Comstock and Robinson (1948, 1952)
- The term "Ideotype" was first proposed by Donald (1968)
- The term "Homeostasis" was coined by Lerner (1954)
- Vander Plank, J.E. (1963) was developed the concept of Vertical and Horizontal Resistance
- The use of "Synthetic Varieties" for commercial cultivation was first suggested by Hayes and Garber (1919)

N. Seed Production in Vegetable Crops

- Leading hybrid vegetable seeds in India: Tomato, okra, chilli
- Indian seed market 6th largest in the world
- Total area under hybrid seed: 23802
- Total production of hybrid seeds: 1410 tonnes
- Monocotyledons: This refers to a plant bearing only one cotyledon or seed leaf when they germinate e.g. Onion
- Dicotyledons: Plants bearing two cotyledons or seed leaves in the seed (e.g. tomato, other crops)
- Cotyledon: supplies energy until the germinating plant is able to photosynthesize
- All seeds contain a juvenile plant embryo and a food reserve normally stored in cotyledon
- Epicotyl: is the emerging growing point above the cotyledons

Two types of germination

- Epigeal germination: the cotyledons appear above ground. The cotyledons emerge from the above the soil, turn green and provides a food and the plant starts to photosynthesize e.g. tomato
- Hypogeal germination: the cotyledons remain below the surface and the epicotyl elongates thrusting the young shoot (plumule) above the soil level, e.g. garden pea, broad bean.
- Seed Priming: is a pre-sowing treatment which controls the water level within seeds to enable germination to take place.
  - Seeds to cycles of wetting and drying.
  - This possibly removes germination inhibitors and improves water uptake when seed is planted, e.g. carrots; soaking seed in water (priming) or chemical primer (e.g. polyethylene glycol) to start germination.

Share (%) of F1 hybrids:

- Cabbage 85% , Brinjal 57%, Tomato 51% ra 40%, Watermelon 44%, cauliflower 13%
- Among the Asian countries in vegetables
- Seed replaceme est producer of hand pollin
- Temperate veg 0%
- On

ncy for biennial vegetables
and seed setting of transplanting

- ★ Cabbage needs vernalization for bolting and flowering
- ★ Commercial seed production of Indian cauliflower done at : North Indian plains
- ★ Snowball cauliflower does not need for chilling requirement but its seed production is done in the temperate regions (mild summer for seed production) in India
- ★ Indian cauliflower: It can form curd and seed production in both plains and hills
- ★ Commercial seed production of Snow Ball cauliflower done at: Saproon valley and Kullu valley of Himachal Pradesh
- ★ Cabbage, Brussels sprouts and Knol-Khol seed production done at Kashmir, upper Kullu valley & Kalpa valley of Himachal Pradesh

Major diseases in cole crops seed production:

- ★ Cole crops: Downy mildew, black rot
- ★ Cauliflower: Sclerotinia rot
- ★ Seed borne disease: Black rot, Black leg and Alternaria leaf spot

Seed yield:

- ★ Indian cauliflower: 500-600 kg/ha
- ★ Snowball cauliflower: 300-500 kg/ha

Optimum temperature for transition from vegetative to reproductive stage:

- ♣ Indian/early/tropical cauliflower: 20° - 25° C
- ♣ Late/snowball cauliflower: 10° - 16° C

Seed recovery/seed ratio

- ♣ Seed dry weight/fresh weight of fruit × 100
- ♣ Seed recovery
- ♣ Tomato: 0.5-1%
- ♣ Brinjal 5-6%

Major seed borne disease in vegetable crops

Crops	Diseases	Scientific name
Beans	Anthracnose	*Colletorichum lindemuthianum*
Garden pea	Ascochyta blight	*Ascochyta pisi*
Legumes	Bacterial blight	*Pseudomonas syringae pv. pisi, Xanthomonas axonopodis*
Brinjal	Phomopsis blight	*Phomopsis vexans*
Cole crops	Black rot	*Xanthomonas campestris pv. campestris*
	Black leg	*Phoma lingam*

Onion

- ♣ The mature bulbs should be stored in well ventilated, cool store (0-4.5°C) for 6 weeks prior to planting
- ♣ Optimum temperature for seed stalk formation: 4-15°C
- ♣ Short day tropical types flower under low temperature 15°C day and 10-12°C night, long day temperate types requires low temperature 0-15°C
- ♣ Best time for planting tropical short day types: October-November
- ♣ Mother bulbs of Rabi crop should be produced and has to be stored up to October. Bulbs must be stored in well-ventilated storage structure with temperature 25-30°C and RH 65-70%
- ♣ Seed yield: 500 – 800 kg seed/ha
- ♣ The seed should be dried in open sun till 6-7 % moisture level
- ♣ Seed rate: 6-8 kg/ha
- ♣ Average bulb weight: 50-80 g, 30-45 q/ha
- ♣ Mother bulb production isolation distance: foundation and certified (minimum distance) 5 m
- ♣ Long rainy periods or heavy dew and fog, favour the development of Stemphylium blight and Purple blotch

Seed to seed method

- ♣ Sowing: June-August
- ♣ Transplanting: August-September
- ♣ Bolting temperature: 10-15°C (January-February)
- ♣ Bulb to seed method

Bulb to seed method

- ♣ Sowing: June-July
- ♣ Transplanting: August-September
- ♣ Bulbs replanting: mid-November-mid-December
- ♣ Bolting time: January-February
- ♣ Biennial: Rabi onion varieties used

Root Crops:

The seeds of Asiatic varieties of root crops are produced in the plains whi... varieties are produced in hills.

1. Seed to seed method
2. Transplanted root to seed method

- ♣ Better method allow us opportunit... thus maintaining only true to th...
- ♣ Stecklings: selected roo... above and lower grou...

F_1 hybrid seed rate of vegetable crops

Crops	Seed rate (g/ha)
Tomato	125
Brinjal	125
Chilli	200
Okra	5000
Cucumber	375
Gourds	5000
Melons	750
Cabbage	250
Cauliflower	250

Hybrid seed production male: female ratio:

- ★ Okra: 1:4
- ★ Musk melon:1:3
- ★ Cucumber: 1:5
- ★ Watermelon: 1:6
- ★ Summer squash: 1:5

Isolation distance:

- ♣ Separation of the seed crops from various sources of contamination to prevent genetic and mechanical contamination

Minimum isolation of distance of vegetable crops:

Sl. No.	Name of group (Crops)	Isolation (m)	
		Foundation seed	Certified seed
1. Cole crops			
	Cabbage	1600	
	Cauliflower	1600	
	Chinese cabbage	1600	
	Knoll-khol	1600	
2. Fruit vegetables			
	Brinjal	200	
	Capsicum (chillies)	400	

F_1 hybrid seed rate of vegetable crops

Crops	Seed rate (g/ha)
Tomato	125
Brinjal	125
Chilli	200
Okra	5000
Cucumber	375
Gourds	5000
Melons	750
Cabbage	250
Cauliflower	250

Hybrid seed production male: female ratio:

- Okra: 1:4
- Musk melon:1:3
- Cucumber: 1:5
- Watermelon: 1:6
- Summer squash: 1:5

Isolation distance:

- Separation of the seed crops from various sources of contamination to prevent genetic and mechanical contamination

Minimum isolation of distance of vegetable crops:

Sl. No.	Name of group (Crops)	Isolation (m)	
		Foundation seed	Certified seed
1. Cole crops			
	Cabbage	1600	1000
	Cauliflower	1600	1000
	Chinese cabbage	1600	1000
	Knoll-khol	1600	1000
2. Fruit vegetables			
	Brinjal	200	100
	Capsicum (chillies)	400	200
	Tomato	50	25
	Okra	400	200
3. Bulbous vegetables			
	Garlic	10	5
	Onion	1000	500
4. Root vegetables			
	Beetroot	1600	800
	Carrot	1000	800
	Radish	1600	1000
	Turnip	1600	1000
5. Tuber vegetables			
	Sweet potato	10	5
	Potato	10	5
6. Rhizomatous vegetables			
	Ginger	10	5
	Turmeric	10	5
7. Legume vegetables			
	Cluster bean	10	5
	Cowpea	10	5
	French bean	10	5
	Indian bean	10	5
	Lima bean	10	5
	Peas	10	5
8. Leafy vegetables			
	Amaranthus	400	200
	Beet leaf	1600	1000
	Coriander	800	400
	Fenugreek	50	25
	Lettuce	50	25
	Spinach	1600	1000
9.	Cucurbits	1000	500

Rouging:

- *Selective removal of undesirable plants from a seeds (Visual inspection)*

Number of roughing in vegetable crops:

- ★ *Tomato: 2*
- ★ *Chilli and capsicum: 3*
- ★ *Cole crops, carrot : 4*
- ★ *Onion: Transplanting method: 4*
  - o *Seed to seed method: 3*
- ★ *Cucurbits and okra: 3*

Seed yield of vegetables

Crops	Seed extraction methods	Seed yield kg/ha
Tomato	Fermentation method/Acid treatment	100-150
Brinjal	Fermentation method	200-300
Chilli	Drying	200-300
Okra	Drying/splitting	1000-1200
Onion		500-800
Cucumber	Drying/Threshing of pods	100-300
Bitter gourd	longitudinal splitting	300-400
Bottle gourd	-	300-500
Musk melon	-	200-300
Water melon	-	400-500
Cabbage	-	400-500
Cauliflower	-	300-400
Knol Khol	-	400
Carrot	-	450-500
Turnip	-	500-600
Garden pea	-	1000-1500
French bean	-	800-1000
Cow pea	-	600-800
Dolichos bean	-	1200-1500
Cluster bean	-	700

Classes of seeds or Seed labels specifications for different seed categories:

India follows 3 generation system (breeder, foundation, and certified deed)

- ★ Breeder Seed (BS): Golden Yellow
- ★ Foundation Seed (FS): White
- ★ Certified Seed (CS): Azure Blue
- ★ Labelled Seed/Truthfully labelled seed (TFL) : Opal Green

Seed testing in vegetable crops:

- ★ Rapid method of seed testing: Tetrazolium test (T_z)
- ★ Testing the mechanical damage of seeds: Ferric chloride test
- ★ Seed vigour test: Brick gravel test (The Hiltner test)
- ★ Testing the variety purity : Grow out test
- ★ Germination % : Paper towel method

Indian Seed Industry:

- ★ National Seed Corporation (NSC) was estabilished in March, 1963
- ★ New Seed Policy (NSP), 1988

Seed regulatory and certification system:

- ★ International seed testing association (ISTA) founded in 1924, Geneva, Switzerland
- ★ Asia and Pacific Seed Association (APSA), Thailand, 1994
- ★ FAO of the UN declared the year 1961-as the World Seed Year
- ★ Seed Act was enacted on 1966
- ★ Seed Rules notified in 1968
- ★ Central seed certification board (CSCB): 1972
- ★ Seed Control Order: 1983
- ★ New seed policy on seed development implemented: 1988
- ★ Seed Bill: 2004
- ★ Central seed laboratory (CSL) located at New Delhi
- ★ Directorate of Seed Research (DSR), Mau Nath Banjan, Uttar Pradesh

Plant variety testing releases and notification in India

- ★ Variety evaluated for 3 years
- ★ IVT: Initial variety trials for one years
- ★ AVT: Advanced variety tri

O. Temperature Regulation in Vegetable Crops

Crops	Effect of temperature	Temperature range (°C)
Tomato	Optimum night temperature for fruit set	15-20°C
	Fail to set fruits	below 13°C and above 37°C
	Optimum temperature for lycopene formation (highest)	21-24°C
	Production of lycopene pigments drops	Above 27°C
Chilli	High temperature leads to poor fruit set	40°C
	Optimum temperature for chilli cultivation	15-35°C
Cabbage	Average temperature for head formation	25°C
	Optimum temperature for growth and heading	15-20°C
	Tropical heat tolerant varieties able to set head	30-35°C
Cauliflower	Bolting for snow ball (late) types	Low temperature (-1 to -2°C)
	Optimum temperature for curd formation	17°C
	Snow ball cauliflower comes flower under	10°C
	Optimum temperature for curd initiation and development	
	Early -I	20-27°C
	Early-II	20-25°C
	Mid-early	16-20°C
	Mid-late	12-16°C
	Late	10-16°C
Carrot	Development best root colour	15.5-21.1°C
	Temperature range for seed germination	7.2-23.9°C
	Optimum temperature for root formation	18-22°C
	Tropical carrot for flower initiation	15-25°C, 1-2 months
	Temperate carrot for flower initiation	5-8°C for 40-60 days
Beetroot	Flower initiation (bolting)	4.5-10° C 1 months
Radish	Optimum Temperature for root flavour, texture and size	10-15°C
	Bolting, high pungency	High temperature > 26°C
Onion	Optimum temperature for seed germination	20-25°C
	Temperature for bulb development	15.6-25.1°C
	Optimum temperature for before bulbing	13-21°C
	Optimum temp for flower initiation	10-12°C
	Best storage temperature for mother bulb for seed production	12°C
Potato	Ideal temperature for tuber development	20°C
	Do not tuberize (night temperature)	Above 27°C
Okra	Optimum temperature for seed germination	25-35°C
	Fastest seed germination	35°C
	Seed germination failed at	Below 17°C
	Flower drop occurs at	Above 42°C
Cucurbits	Most of the cucurbits need day temperature for seed germination	Above 25°C
	Optimum soil temperature for seed germination	18-25°C
Musk melon	Temperature for fruit developmental stage	35-40°C
Cucumber	Female flower production reduced at	Above 30°C
Water melon	Average temperature for normal vegetative growth	25-30°C

P. Role of PGR in Vegetable Crops

Crops	PGR	Effects	Remarks
Tomato	Tomatotone or Tomatolan (4-CPA)	Enhance the fruit set at high temperature 34/20°C	Apply at flower clusters
	2,4D @ 2-5 ppm	Increase the fruit set, earliness and parthenocarpy	Seed treatment
	PCPA @ 50-100 ppm	Fruit set under high and low temperature conditions	-
Brinjal	2,4–D @ 2 ppm	Improve the fruit set, early yield	Spray at first flower appearance
Chilli	NAA @ 40 ppm	Enhances the flower and fruit set	-
	GA_3 @ 10-100 ppm	Enhances the flower and fruit set	-
Okra	IAA @ 20 ppm, NAA @ 20 ppm	Enhances the seed germination	-
Bottle gourd	MH @ 50-150 ppm	Induction of female flowers	-
Ridge gourd and sponge gourd	IAA @ 20-200 ppm	Induction of female flowers	-
	NAA @ 25-100 ppm	Induction of female flowers	-
Water melon	TIBA @ 25-250 ppm	Induction of female flowers	2 & 4 true leaf stage
Musk melon	Ethrel @ 250 ppm	Increase the female flower production	2 & 4 true leaf stage
Musk melon (Gynoecious lines)	Sliver thiosulphate $[Ag(S_2O_3)_2]^{3-}$) @ 300-400 ppm	Induction or formation of male flowers	2 & 4 true leaf stage
Cucumber	Ethrel @ 150-200 ppm	Increase the female flower production	-
Cucumber (Gynoecious lines)	Silver nitrate ($AgNO_3$) @ 200-300 ppm	Induction of male and morphologically functional bisexual flowers	2 & 4 true leaf stage
	Silver thiosulphate (STS)	Induces male flowers	2 & 4 true leaf stage
	Amino ethoxyvinyl glycine (AVG) @ 50-100 ppm	Induces of male flowers	
	GA_3 @ 1500-2000 ppm	Induction of male flowers	2 & 4 true leaf stage
Bitter gourd	CCC @ 100-500 ppm	Increase the female male ratio	-
	MH @ 150-200 ppm	Increase the female flowers	-
Bitter gourd (Gynoecious lines)	Silver nitrate ($AgNO_3$) @ 200-300 ppm	Induce male flowers (commercially used)	-
Summer squash	Ethephon @ 250 ppm	Temporarily suppression of male flowers	1st true leaf stage Repeated spray up to 2-3 weeks
	Ethephon @ 600 ppm (Commercials utilization for hybrid seed production	Complete suppression of male flowers	2 & 4 true leaf stage Repeated spray up to 2-3 weeks
Pumpkin	Ethephon @ 250 ppm	High female flower production	-
Garden pea	CCC @ 50 ppm	Increase the yield, drought tolerance	-
	GA_3 @ 50 ppm	Increase the yield	-
Onion	Maleic Hydrazide (MH) @ 1500-2000 ppm	Sprout suppresant	Application at before harvest
Potato	GA_3 @ 10-15 ppm	Breaking the tuber dormancy Enhances the sprouting	Duration : 10-20 minutes
	Thiourea @ 1%	Breaking the tuber dormancy	-
	Maleic Hydrazide (MH)	Sprout inhibitors	-
	Chloropropham (CIPC) @ 25 mg/tonnes of tubers	Sprout inhibitors (suitable fo storage)	

Q. Virus and Phytoplasma Diseases of Vegetable Crops

Diseases	Causal organism	Vectors	Remarks
Beans			
Yellow mosaic	Virus		30-40% yield loss
Bitter gourd			
Mosaic	Virus	Aphids	
Witches broom	Mycoplasma like organisms	Leaf hoppers	
Brinjal			
Little leaf	Mycoplasma like organisms	Leaf hoppers	
Chilli			
Leaf curl	Virus	White fly	Abaxial curling of leaves
Spotted wilt	Virus	Thrips	70-80% yield loss
Watermelon			
Mosaic	Virus	Aphids	
Bud necrosis	Virus	Thrips	
Tomato			
Leaf curl	Virus	White fly	
Tomato mosaic	Virus	Contact and seed	
Spotted wilt	Virus	Thrips	
Fern leaf	Virus	Aphids	
Potato			
Potato leaf roll	Virus	Aphids (*Myzus persicae*)	Net necrosis of vascular tissue of tubers
Spindle tuber	Viroid	Mechanical	Tuber surface cracking
Potato virus A	Virus	Aphids	Mild mosaic
Potato virus X	Virus		
Potato virus Y	Virus	Aphids (*Myzus persicae*)	Severe mosaic
Radish			
Mosaic I, Mosaic II	Virus	Aphids	
Phyllody	MLO's	Phyllody	
Pumpkin			
Mosaic	Virus	Aphids	
Yellow vein mosaic	Virus	White fly	
French bean			
Common mosaic	Virus	Aphids	
Golden mosaic	Virus	White fly	
Phyllody	MLO's	Leafy hopper	
Cucumber			
Mosaic	Virus	Aphids and seeds	
Green mottle mosaic	Virus	Seeds	
Phyllody	MLO's	Leaf hopper	
Cowpea			
Mosaic	Virus	Aphids	
Yellow flecks	Virus	White fly	

Major post harvest diseases of vegetables

Crops	Disease	Pathogens
Leafy vegetables	Grey mould rot	*Botrytis cinerea*
Potato, leafy vegetables	Bacterial soft rot	*Erwinia carotovora*
	Dry rot	*Fusarium* spp
Sweet potato	Black rot	*Ceratocystis fimbriata*
Leafy vegetables, carrot	Watery	

Calcium related disorders of vegetables

Vegetables	Examples
Bean	Hypocotyl necrosis
Tomato	Blossom end rot (BER), black seed, cracking
Water melon	Blossom end rot (BER)
Brussels sprout	Internal browning
Cabbage	Internal tip burn
Chinese cabbage	Internal tip burn
Carrot	Cavity spot, cracking
Celery	Black heart
Chicory	Black heart, tip burn
Lettuce	Tip-burn
Parsnip	Cavity spot
Potato	Sprout failure, tip burn

CPK

R. Points to Ponder

- Tetradynamous anther type is the main feature of family Brassicaceae
- Solanaceae family is also called as Night Shade Family
- Tapioca is richest source of carbohydrate and calories (38.1 g/100g of edible part) followed by Sweet Potato
- Parsley is the rich source of Vitamin-C (281 mg/100g)
- Orange flesh Sweet potato is rich source of Vitamin-A (14190 µg/100g)
- Vegetable crop varieties rich source of carotene: Carrot-Pusa Yamadagni and Pusa Meghali, Pumpkin-Arka Chandan, Palak -Pusa Jyoti, Beet Root -Pusa Swarnima
- Cereals deficient amino acid: Lysine
- Pulses and oilseeds deficient sulphur containing amino acids (*i.e.* methionine, cysteine and cystine) but rich in Lysine
- RDA stands Recommended Dietary Allowance
- Vitamin-C rich vegetables: Cabbage (124 mg/100g), Bitter gourd (88 mg/100g), Knol-Khol (85 mg/100g)
- Leafy vegetables Rich Vitamin-A: Spinach, Cabbage, Broccoli, Asparagus
- Poor source of Proteins: Leafy vegetables, Root and Tuber Crops
- Water soluble antioxidant: Vitamin-C
- Low oxalic acid vegetable: Palak
- High oxalic acid vegetable: Spinach
- Dicholinous bearing vegetable: Bread fruit
- Among the group of leafy salad vegetables, highly nutritious: Spinach
- Chilli can tolerate extreme climate than tomato and brinjal
- Seooping and Blanching practices related to cauliflower cultivation
- Root nodules absent legume crop: French Bean
- Frost resistant bean: Broad Bean
- Most ancient type of bean: Indian Bean
- Frost sensitive cucurbit: Melon
- Frost tolerant cucu
- Ridge gourd
- Pumpkin
- for

high RH well

- Radish useful for intercrop and companion planting in other vegetable crops
- Tolerant to frost better than most other vegetables: Spinach
- In all root vegetables root to seed method seed production is used for nucleus and breeder seed production
- Among the root crops high source of vitamins found in Radish
- High starch content: Yam 25%
- High dry matter content: Potato
- High calorie diet vegetable: Sweet Potato
- Among the leafy vegetables which one have highest Vitamins of A, B_1,B_2,B_3,B: Palak
- Folic acid rich vegetables: Spinach and Palak
- Folic acid (Folate) is found in abundance in Spinach 123µg/100g, other green leafy vegetables 148µg and beans 144 µg/100g
- Oxalic acid high in Amaranthus
- Green beans: rich source of Calcium
- Broccoli: Rich source of Calcium and Vitamin-A
- Carotenoid (Lutein) present in dark green leafy vegetables
- Among the cruciferous, high antioxidant vegetable: Kale
- Among the cruciferous, Glucosinolate content high in Brussels sprouts
- Largest group of plant secondary metabolites: Flavonoids
- Tomato contains high level of Flavaonols (1.3-22.2 mg/100g F.W.).
- Rich source of Proteins: Legumes (6-7%)
- C_4 plants: Amaranthus, Basella
- Most abundant Fat soluble Antioxidant: Vitamin-K
- Garden Beet, Sugar Beet, Swiss Chard, Palak: These all vegetable are same genus and species
- Among the vegetables, Beetroot contains highest sugar (sucrose) content (8 g/100g)
- Sweet corn and peas are more rich in sugar content at immature stage
- All fruits are acidic in nature whereas vegetables are alkaline except tomato
- Lachrymatory factor in onion: Thiopropanl-S-oxide

Mushrooms

- Mushroom rich source of protein and having 9 essential amino acids
- Mushroom source of lovastatin: reduce the cholesterol level
- Only vegetable source of Vitamin D
- Mushroom city of India: Solan

- Directorate of Mushroom Research (DMR), Solan, Himachal Pradesh (HP) (Previously known as National Research Centre on Mushroom)

Total cultivated edible mushroom types: 4

- ★ White button mushroom: *Agaricus bisporus* (90% of India's total mushroom production), Grown at low temperature (16-18°C)
- ★ Oyster mushroom: *Pleurotus spp.*
- ★ Paddy straw mushroom: *Volvariella spp.* Grown at high temperature (above 30°C)
- ★ Milky mushroom: *Calocybe indica*, commercially grown in south india

Other mushroom species:

- ★ Wood ear mushroom: *Auricularia spp.*
- ★ Shiitake mushroom: *Lentinus edodes*
- ★ Giant mushroom: *Stropharia rugosoannulata*

Varieties:

- Button mushroom: Ooty-1, Ooty (BM)-2: Both varieties are good keeping quality
- Oyster mushroom: Ooty-1
- Pink Oyster mushroom (*Pleurotus eous*): APK-1
- Elm oyster mushroom (*Hypsizygous ulmarius*): OO-2

★ Cobweb diseases (Greyish white mycelium): Major disease in mushroom

★ Abiotic disorders

- Scales- fluctuating RH
- Rose comb - exposure to diesel fumes
- Long stem: presence of high CO_2

★ Sciarid mushroom flies: *Bradysia tritici*, *Sciara spp.*, and *Lycoriella auripila*

★ Poisonous mushrooms: *Amanita muscaria*, *Amanita phalloides*, *Morchella tuleciyana*, *Boletus edulis*

Chapter-5 : Floriculture

A. Introduction to Floriculture

- ★ Floriculture: Floriculture: deals with commercial growing, marketing and arranging flowers and ornamental plants, which includes annuals, biennials and perennials viz., trees, shrubs, climbers and herbaceous perennials.
- ★ Landscaping: is the design and alternation of a portion of land by use of planting material and land reconstructions
- ★ Ornamentals: A wide variety of plant materials are grown and harvested for their ornamental value including ferns and lycopodiums, gymnosperms (pines, firs, podocarps etc.) and angiosperms (the flowering plants).
  - ✦ Ornamentals: include those that are cut for their flowers and/or foliage, and those that are sold as potted flowering plants or potted foliage plants.
- ★ Garden - originated from the latin term Gyrdan meaning to enclose
- ★ Traditional flowers (or) economic flowers (or) loose flowers: Jasmine – Mullai, Pitchi, Malligai and Kakada, Scented Rose-Edward and Andhra Red Rose, Chrysanthemum, Tuberose, Marigold, Crossandra
- ★ Non-Traditional flowers: Aster, dahlia, nerium, golden rod, gomphrena, barleria, celosia
- ★ Flower bulbs, also called ornamental geophytes
- ★ Flower bulb industry dominated by 7 genera: Tulip, lilium, narcissus, gladiolus, hyacinthus, crocus, and iris
- ★ Netherlands, the leading bulb producer worldwide
- ★ Cut flowers: Rose, Chrysanthemum, Gladiolus, Orchid, Carnation, Anthurium, Gerbera
- ★ Speciality Cutflowers: Statice, Stock, Bird of Paradise, Gypsophila, Liliums, Antirrhinum, Heliconia
- ★ Flower of Lotus is used as the locket of the garland
- ★ Arun Titan (*Amorphophallus titanium*): largest flower in the world
- ★ Rose cultivars presently demand in the cut flower market:
  - o Raktagandha, Sindhoor and Arjun
- ★ Gladiolus cultivars presently demand in the cut flower market:
  - o Carmine, Happy End, Hunting Song, Peter Pears, Spick and Span
- ★ Carnation cultivars presently demand in the cut flower market:
  - o Standard type: Arthur Sim, William Sim and Shocking Pink
  - o Spray type: Orange Elf, Peachy, Goldilocks and Exquisite

MAJOR CULTIVARS OF FLOWER CROPS:

IIHR Varieties

Rose
- ✦ Arka Parimala
- ✦ Kiran
- ✦ Dr.G.S.Randhawa
- ✦ Nishkant

Carnation
- ✦ Arka Tejas Arka Flame
- ✦ IIHRP-1

Chrysanthemum
- ✦ Arka Pink Star
- ✦ Arka Ravi
- ✦ Chandrakant
- ✦ Indira
- ✦ Nilima
- ✦ Rakhee
- ✦ Usahkiran
- ✦ Arka Ganga
- ✦ Arka Swarna
- ✦ Chandrika
- ✦ Keerti
- ✦ Pankaj
- ✦ Ravikiran
- ✦ Yellow Gold

Gerbera
- ✦ Arka Krishika

Gladiolus:
- ✦ Aarti
- ✦ Darshan
- ✦ Kumkum
- ✦ Nazrana
- ✦ Sapna
- ✦ Shakti
- ✦ Sindur
- ✦ Arka Kesar
- ✦ Aikta
- ✦ Arunodaya
- ✦ Basant
- ✦ Sundari
- ✦ Chitralekha
- ✦ Geetanjali
- ✦ Nartaki
- ✦ Arka Amar
- ✦ Apsara
- ✦ Dhiraj
- ✦ Meera
- ✦ Poonam
- ✦ Sagar
- ✦ Shobha
- ✦ Tilak
- ✦ Arka Suvarna
- ✦ Anuradha
- ✦ Ashirwad
- ✦ Bharat
- ✦ Benazeer
- ✦ Dilruba
- ✦ Joga
- ✦ [illegible]

Tuberose
- ✦ *Shringar*
- ✦ *Prajwal*
- ✦ *Arka*

Hibiscus
- ✦ *Neelofer*
- ✦ *Phulkari*
- ✦ *Queen of Hessaraghatta*
- ✦ *Red Gold*
- ✦ *Shanti*
- ✦ *Smt. Kamala Nehru*

China aster:
- ✦ *Kamini*
- ✦ *Shashank*

Bougainvillea
- ★ *Chitravathi*
- ★ *Jawahar Lal Nehru*
- ★ *Sholay*
- ✦ Suvasini
- ✦ Vaibhav
- ✦ Nirantara
- ✦ Pakeezah
- ✦ Priya
- ✦ Ratna
- ✦ Red Saturn
- ✦ Smt. Indira Gandhi
- ✦ Tribal Queen
- ✦ Poornima
- ✦ Violet Cushion
- ✦ Dr HB Singh
- ★ Purple Wonder
- ★ Usha

★ **Classification of fruits based on photoperiodic response**

1. **Short day plants:** Gardenia, Poinsettia, Kalanchoe, Bryophyllum, *Viola*
2. **Long day plants:** Baby's breath, Spider plant, Fuchsia, Rex begonia, Evening primrose

Important flower breeders in India:

★ Eminent breeder of jasmine in India: S. Muthuswamy, Madhava Rao, Bhupal Rao H.C.Šrivastava,

★ Eminent breeder of chrysanthemum in India: M.A.Kher, S.K.Dutta, M.N.Gupta

★ Famous Hibiscus breeder in India: R.N.Bhatt, M.Virupaksha

★ Important rose breeder in India: B.P.Bal, S.C.Dey, J.P.Agarwal, A.P.Singh

★ Important gladiolus breeder in India:
- o Bajrang Bahadur Singh Bhandari, R.L.Mishra, S.S.Negi, D.Mukherjee

★ Important breeder in Dahlia: Swami Vinayanda, P.K.Das, A.K.Dey

★ All India Coordinated Research Project (AICRP) on Floriculture during 1970-71

★ The Directorate of Floricultural Research (DFR), an Institute established up-gradation of Project Coordinator's cell of All India Coordinated Research Project (AICRP) on Floriculture during the XI Plan

B. Principles of Gardening

1. **Mughal garden**
2. **Japanese gardens**
3. **English gardens**
   - ♣ **Gardens in India**
   - ♣ **International gardens**
4. **Flower arrangement**
   - ♣ **Japanese style of flower arrangement**
5. **Dry flower arrangement**

★ Aesthetic refers to sense perception of beauty

★ Components of beauty: Colour, shape, texture, pattern, line and point

★ Terrarium: Big sized bottles with narrow mouth are used to grow the house plants

★ Best plants for growing in varandahs: *Livistonia, Thrinaxx, Caryota, Areca lutescesns, Ferns*

★ **Hedges:** Shrub is planted on boundary for fencing and is used for ornamental and protective purpose eg. *Lantana, Inga*

★ **Edges** (20-30cm): Low growing perennial plants are grown on the border of plots or beds eg. *Irisine, Alternanthera*

★ **Topiary:** Art of training plants into different shapes like birds, animals, domes and Umbrellas eg. *Clerodendraon, Duranta, Thuja*

★ **Trophy:** Arrangement of potted colourful foliage/flowering shrubs/flowering annuals/herbaceous perennial around a tree or any central object

★ **Herbaceous border:** Planting of annuals in the border of plots

★ **Hanging baskets:** Trailing of plants in container which is suitable for indoor and outdoor conditions eg. *Verbena, Petunia, Zebrina*

★ **Carpet bedding:** Covering on area [illegible] beds with dense low growing herbaceous plant[illegible] *Alternanthera*

★ Floral ca[illegible]

★ Plan[illegible] floral materials

★ [illegible] *Portulaca*

Free sty[illegible]

1. **Mughal garden:**

- Introduction of Mughal garden to India: Baber
- Famous garden style of India is Mughal garden: Replica of the ancient Persian garden
- Gardening style of Mughal was basic form of Char Bagh design of Paradise garden of Persia
- Running water is the life of Mughal garden
- Baradari is a canopied structure with 12 doors, specific feature of Mughal garden
- Chabutras or stone platforms, High protecting wall, Terminal building, Entrance gate, Terrace and Baradari are important features of Mughal garden
- Garden shape: Rectangular or square style
- **Symbolisim in Mogual gardens:**
  - Naharas or water is source of life
  - Cypress→ immortality, Flowering trees + waterways →renewal of life respectively
  - White Kachnar (*Bauhinia alba*) represents the youth and life
  - Terminal building *e.g.* Taj Mahal, Agra, Uttar Pradesh
- **Mughal garden in India:**
  - Pinjore garden or Yadavindra garden, Pinjore (Haryana)
  - Taj Mahal, Agra, Uttar Pradesh (UP)
  - Ram Bagh, Agra (UP)
  - Mehtab Bagh, Agra (UP)
  - Khusro Bagh, Allahabad (UP)
  - Roshanara Garden, New Delhi
  - Humayun's tomb, Nizamuddin, New Delhi
  - Rashtrapati Bhavan (President House), New Delhi
  - Safdarjung's Tomb, New Delhi
  - Shalimar Bagh, Srinagar (Jammu and Kashmir)
  - Nishat Gardens, Srinagar (Jammu and Kashmir)
- Main concept of Persian paradise: Naharas or flowing water canals
  - *e.g. Charbagh or Chahar Bagh*, New Delhi

2. **Japanese gardens:**

- Also known as 'Nature in miniature'
- Famous in the world for their unique style, natural, spiritual beauty and calmness
- Japanese natural landscape elements of the country: Mountains, Islands, Rivers, Lakes, Streams, Bridges
- Prominent features of Japanese gardens: Water, stones and evergreen plants
- Type of Japanese gardens: Hill garden, Tea garden and Flat garden

- Hill garden is known in Japanese as *Tsukiyama niwa* or *Tsukiyama-sansui* (means hills and water)
- Flat garden is called as *Hira-niwa* in Japanese language
- Flat gardens are devoid of hills, streams or ponds
- Flat garden represents a mountain valley or meadow land
- Sand garden is the totally devoid of plants
- **Example for Japanese gardens:**
  - *Ryoanji garden*, Kyoto', Japan- Most famous sand garden
  - *Roji-niwa* is also known as passage garden
  - Buddha Jayanti Garden, New Delhi

3. **English gardens:** (Formation of formalism and naturalism)

- Amongst all European gardens most beautiful garden is English garden
- Cottage gardens are small gardens which are made around lower and middle class people
- Main feature of English garden: Lawn, Herbaceous garden, Rockery
- Rockery: an idea of a mountain or alpine garden with plants growing in the crevices of rocks
- Cottage gardens was developed by Gertrude Jekyell
- English garden architect: Repton and Capability
- French garden architect: Le Notre
- Term "bioaesthetic planning" coined by Professor Lancelot Hogben
- Wild garden and herbaceous border was expounded by William Robinson
- Hedge of Yew and topiary are common features of cottage gardens
- Royal Botanical Garden (1757) is located at Kew, England
- Royal Horticultural Society (RHS) was established in 1804
- Indian Horticultural Society (IHS) was established in 1942
- Royal Agri-Horticultural Society garden is located at Kolkata

Bonsai: Origin: China

- Bonsai is the ancient Japanese craft of dwarfing trees
- Japanese art of growing miniature trees and shrubs in containers
- Optimum size of bonsai: 30 to 60 cm
- Wiring needs to bonsai to get different shape
- Root pruning and repotting is a necessary pr
- Renown person for bonsai: V.P.Agnihotr
- Suitable plants: *Ficus religios* *bengalensis*

Gardens in India:

- ★ Bryant Park is located at Kodaikanal, Tamil Nadu
- ★ Botanical Garden is located at Ooty, Tamil Nadu
- ★ Sim's Park, Conoor, Nilgiris, Tamil Nadu
- ★ King Hyder Ali established most famous Lal Bagh garden in Bangalore, Karnataka
- ★ Floral clock is the special feature of Lal Bagh garden
- ★ Brindavan Gardens, Krishnarajasagara dam, Mysore, Karnataka
- ★ Baradari garden is located at Patiala, Punjab
- ★ Rose Garden of Chandigarh and Ludhiana, Punjab
- ★ Asia's largest tulip garden: Indira Gandhi Memorial Tulip Garden, Dal Lake, Jammu and Kashmir

International gardens:

- ★ International rose garden of Kortrijk, Belgium
- ★ World largest rose garden: Peggy Rockefeller Rose Garden in New York Botanical Garden, New York
- ★ Royal National Rose Society Gardens (formerly The Gardens of The Rose), Chiswell Green, UK
- ★ World famous tulip garden: Keukenhof Gardens, Amsterdam, Netherland

4. Flower arrangement

- ★ The term 'flower' in flower arrangement includes fresh flowers, foliage, dried twig and fruits (dry and fresh)
- ★ Veni: A special kind of flower arrangement is widely used in South India to decorate the long plait of hair (Veni) at the time of *Bharat Natyam* or during marriage ceremonies
- ★ 2 styles of flower arrangement: Occidental and Oriental style
- ★ Occidental or western or British style: Massing of flowers
- ★ Oriental or Eastern Style: Line arrangement with foliage and flowers
- ★ Historically, oriental style involves religious symbolism and Zen-Buddhism *i.e.* Japanese flower arrangement
- ★ Japanese style flower arrangement is called as "*Ikebana*"
- ★ 3 basic lines in Japanese flower arrangement: Earth (Hikae), Man (Soe), Heaven (Shin)
- ★ In Japanese language fillers means '*Jushi*'

Japanese style of flower arrangement:

Styles	Features	Other name
Morimona	Fruits, vegetable and flower are arranged	English flower arrangement
Moribana	Piled flowers in shallow containers	Natural Ikebana
Nageire	Flowers are 1½ times taller than flower vase	Western style
Jiyubana	Moibana + Nageire styles	Free flower arrangement
Zeneibana	Beautiful sculpture using wood, stone, rocks and metals	Depicting any natural scenery
Zeneika	Straight material with uneven height	Abstract style and does not simulate nature

5. Dry flower arrangement:

- ★ Potpourri is a mixture of dried, sweet-scented plant parts including flowers, leaves, seeds, stems and roots
- ★ Glycerine method (Glycerining) is commercially used for foliage preservation
- ★ Skeletonizing (lacy appearance of veins) is done for *Ficus religiosa*
- ★ Other preservation methods: Burying in sand/borax/silica gel
- ★ Oven drying method:
  - ☆ Helipterum, Chrysanthemum, Gerbera, and Limonium: 45-49° C @ 48 hrs
  - ☆ French marigold: 45-49° C @ 72 hrs
  - ☆ African marigold: 45-49° C @ 96 hrs
  - ☆ Zinnia and delphinium: 40-44°C @ 48 hrs

C. Loose Flowers

1. Jasmine
2. Crossandra
3. Tuberose
4. Chrysanthemum
5. Marigold
6. Hibiscus

1. Jasmine

1. **Jasmine:** *Jasminum spp.*: Oleaceae: 2n=26: Origin: India
   - ★ The word jasmine comes from *Arabic* word "Yasmine"
   - ★ Oldest fragrant flowers cultivated by man
   - ★ Jasmines introduced to India in the mid-sixteenth century
   - ★ Invaluable bridal garland and Veni prepared from jasmine flower bud
   - ★ *J. sambac*, which is mainly grown for flowers
   - ★ Jasmine is perennial plant
   - ★ Origin of Arabian jasmine: East Indies or India; Spanish jasmine: Persea and Mullai: South India

Important Jasminum species:

Common Name	Scientific Name	Pruning time	Spacing	Yield (Kg/ha)
Arabian /Tuscan Jasmine	*Jasminum sambac*	October end	1.2 × 1.2	1000-1600
Mullai	*Jasminum auriculatum*	December to January	1.8 × 1.8	
Royal/Spanish/French/ Catalonian Jasmine	*Jasminum grandiflorum*	Mid-December	1.5 × 1.5 or 1.8 × 1.8	1500-2000
Yellow/Italian Jasmine	*Jasminum humile*	Flowering time: April to June		Shrub
Tree Jasmine	*Jasminum arborescens*	Flowering time: November to May		Shrubbery tree
Climbing Jasmine	*Jasminum flexile*	Winter and Early Spring		
Pandal Malli	*Jasminum calophyllum*	February to June	Woody vine	
Rosy jasmine	*Jasminum baesianum*			
White jasmine	*Jasminum officinale*	Spring		

- ★ Most commercially grown species in India: *Jasminum sambac*: Sensitive to frost
- ★ Double flowering types of *J. sambac* is known as Motia or Mogra
- ★ Excellent pot plant species: *J. polyanthem*
- ★ Most successful method of layering in Jasmine: Ground Layering
- ★ Planting time: June to November
- ★ Effective substitute for normal pruning: Pentachlorophenol (Chemical defoliants)
- ★ Early flower production: CCC@1000ppm and induction of number of laterals: SADH @ 1000ppm
- ★ Seed viability: 10 months
- ★ Best time of harvest for the extraction of concrete is early morning (6-8A.M)
- ★ 1 tonne of fresh jasmine flowers gave concrete yield: 2.8-3kg and obsolete yield 1.3-1.5kg
- ★ Eminent breeder of jasmine in India: S. Muthuswamy, Madhava Rao, Bhupal Rao H.C. Srivastava,

Varieties:

Mullai (*Jasminum auriculatum*)	CO-1: Resistant to Gall mites
	CO-2
	Pari Mullai
Pitchi (*Jasminum grandiflorum*)	CO-1: Pitchi
	CO-2: Pitchi
	Arka Surabhi

- ★ Madurai jasmine (Tamil Nadu) known for fragrance in world
- ★ Maturity stage for concrete extraction: Fully opened flowers
- ★ World famous jasmine oil extracted from Spanish Jasmine
- ★ World best quality jasmine perfume produced in France (Grasse region)
- ★ World leading producer of jasmine oil: France
- ★ Jasmine concrete (Wax like substance containing natural perfume with waxes and colouring material) mostly extracted from *Jasminum grandiflorum*
- ★ It is being used in cosmetic industries and it fetches very high price in the international and domestic market
- ★ The jasmine flowers contain 0.25% of the perf… volatile oil and it can be extracted by means of solvent extraction me…
- ★ Alcohol extraction best meth…
- ★ 1 kg of jasmine conc…
- ★ Jasmine absolute…

Important species	Shelf life	Concrete recovery (%)	Concrete yield (Kg/ha of flowers)
Jasminum sambac	28-30 hrs	0.14-0.19	13-28
Jasminum auriculatum	28-40 hrs	0.28-0.36	11-15
Jasminum grandiflorum	24 hrs	0.25-0.32	13.5-20

2. Crossandra

2. **Crossandra/ firecracker flower:** *Crossandra infundibuliformis:* Acanthaceae: 2n=40
Origin: Indo-Malaya region

- ★ *Tropical evergreen shrub*
- ★ *Crossandra is a polyploidy crop*
- ★ *Delhi Crossandra is a triploid, 2n=30 (Bright red colour)*
- ★ *Orange crossandra is tetraploid: 2n=40 (orange-yellow colour)*
- ★ *C.flava:* Unbranched, short stemmed shrub with bright yellow flowers
- ★ *Popular hair adornment flower in South Tamil Nadu*
- ★ *Type of inflorescence: Spike*
- ★ *Commercially propagation: Seeds*
- ★ *Seed rate: 5 kg/ha*
- ★ *Delhi crossandra is commercially propagation: Stem cuttings*
- ★ *Pruning is important practice done in Late winter*
- ★ *Crossandra wilt: Fusarium solani*
- ★ *Harvesting stage: When the corolla out of the calyx*
- ★ *About 15000 flowers make 1kg*
- ★ *Yield: 2000 kg of flowers/ha*
- ★ *Delhi crossandra: 2800kg/ha*
  - ☆ Orange : With orange coloured flowers
  - ☆ Delhi : Bright deep orange flowers
  - ☆ Lutea yellow : Orange yellow colour flowers
  - ☆ Sebaculis Red : Hardy cultivar-Tolerant to nematode
- ★ TNAU: Co-1 (yellowish orange), Soundarya (Pink colour)
- ★ **IIHR Varieties:** Arka Kanaka (bright orange colour), Arka Ambara (Biggest corolla size, orange red colour)

- ★ **Mutant variety:** Kanakadhara (mutant of Delhi crossandra, bright orange colour)
- ★ **Exotic variety:** Fortuna, Diane
- ★ **Major breeding work done in India:** TNAU, IIHR

3. Tuberose (also - Amaryllidaceae)

3. **Rajanigandha/Tuberose:** *Polianthes tuberosa:* Asparagaceae: Origin: Mexico

- ★ Tropical flower crop
- ★ Tuberose is half-hardy, monocotyledon herbaceous perennial, bulbous plant
- ★ It is popularly known as Rajanigandha or Nishigandha
- ★ It occupies a prime position in the country among the commercial ornamental bulbous crops
- ★ Highly adapted to subtropical condition (North Indian plains: April-November)
- ★ Hardy, perennial bulbous plant
- ★ Multipurpose flowering plant
- ★ Prefers warm humid climate
- ★ Optimum temperature for growth and development: 25-28°C
- ★ Long day promotes vegetative growth and emergence of flower
- ★ Inflorescence: spikes, opens acropetally (i.e., from base to top of the spike)
- ★ Flowers of the Single type (single row of perianth) are commonly used for extraction of essential oil, loose flowers, making garland.
- ★ Double varieties (more than two rows of perianth) are used as cut flowers, garden display and interior decoration.
- ★ Single type varieties are more fragrant than Double type
- ★ Single types contain 0.08 to 0.14 percent concrete which is used in high grade perfumes
- ★ Perfume industry popular in France (Siagne River Valley)
- ★ *P. howardii*: source for breeding colourd flowers

Major types:

Types	Characters	Purpose
Single	Single row of tepals, highly fragrant type	Cut flower, loose flower, essential oil
Double	Bears more than 3 rows of tepals	Cut flower
Semi-double	Flowers with 2-3 rows of tepals	Cut flower

Varieties:

- ☆ Mexican Single: Traditional variety, highest recovery of concrete

MPKV, Rahuri:

☆ Phule Rajani: Dual purpose variety

NBRI Varieties: Two varieties were released based on gamma irradiation

☆ Rajat Rekha: Single type

☆ Swarna Rekha: Double type

★ IIHR Varieties:

Varieties	Types	Purpose
Shringar	Single type	Cut, loose and perfume
Prajwal	Single type	Cut, loose and perfume
Arka Nirantara	Single type	Longer blooming period
Vaibhav	Double type	Cut flower and Perfume
Suvasini	Double type	Only for cut flower

★ Calcutta single and Kolkata Double are the promising types for Tamil Nadu

★ Offseason variety: Shringar

★ Commercial propagation: Bulb

★ Ideal bulb size for planting: 25-30 g (Bulb diameter 2 cm or more)

★ Bulb diameter (1.5 to 3.0 cm) suitable for planting. About 1.25 - 1.5 lakh bulbs/ha (8 to 9 tons of bulbs) ha

★ Breaking bulb dormancy: Dipping the bulbs in 4% solution of thiourea for 1 hour

★ Planting time: June to July

★ Optimum planting time for Delhi condition: March-April

★ Tuberose normally begins to flower in 85 to 90 days after sprouting and continues to flower throughout the year

★ Enhancing flower yield: Dipping of bulbs in CCC @ 5000 ppm

★ Loose flower yield:10-15 tonnes/ha

★ Tuberose concrete and absolute prepared from the flowers of tuberose

★ Tuberose grown for extraction of essential oil: Grasse region of South France and in Morocco

★ French perfume is considered one of the best in the world

★ Concrete extraction: Solvent extraction method

★ Concrete yield: 2-2.8 kg/h

★ Serious problem in tuberose cultivation: *Aphelenchoides besseyi* (Foliage nematode)

4. Marigold

4. Marigold: *Tagetus spp.*: Asteraceae: Origin: Central and South America (Mexico)

Groups	Botanical name	Chr. no.	Origin	Types	Start to flower
African marigold	*Tagetus erecta*	2n=2x=24	Mexico	Taller type	2-2 ½ months
French marigold	*Tagetus patula*	2n=4x=48	Mexico & South America	Dwarf type	2 ½ - 3 months
Single signet	*Tagetus tenuifolia*	2n=2x=24	Bushy type (< 30 cm)	Dwarf type	
Sweet scented marigold	*Tagetus lucida*	2n=2x=22			
Californian Marigold	*T .lacera*				
Shrubby Marigold	*T. lemmonii*				
Mystery marigold	*T. sarmentosa*				

★ Receptacle less flower

★ African marigold is also known as *Rose of Indies*

★ Highest essential oil content: *Tagetus signata*: Suitable for perfume industry

★ Essential oils yielding species: *T. minuta* and *T. erecta*

★ Essential oil content of fresh matured flowers: 1.25 %

★ Wild marigold: *Tagetus minuta*: Suitable for essential oil extraction for perfume and cosmetics commonly found in North West Himalayas

★ French marigold is dwarf in nature and profuse flowering

★ French marigold is most ideal for rockery, edging, hanging baskets and window boxes

★ Used as a cover crops that can reduce ne…

★ Marigold produces a substance … reduces the root-knot nematodes infection

★ Optimum temperature for se…

★ Highest content of zea… poultry to increase th…

★ Xanthophylls (…

★ African m…

Aphytochemical found in plants (many) of Asteraceae family.

- Helenine- Used for eye adaptability to distinct light intensity
- French marigold is ideal for rockery, hanging baskets and window boxes
- French marigold is allotetraploid species between *T. erecta* × *T. tenuifolia*
- Interspecific hybrids between African marigold and French marigold developed by USA
- Type of male sterility: Genetic male sterility (GMS): 2: Types 1. Apetalous 2. Double flowered
- GMS is controlled by single recessive gene
- Pinching is done 40days after transplanting
- Marigold is cross pollinated crop
- Seed rate: 800g-1.5 kg/ha; Seed viability: 6-8 months

Yield:

- African marigold: 11-18 t/ha
- French marigold: 8-12 t/ha

- Volatile oil content of French marigold: 0.5-1.5%
- Marigold oil recovery: 0.20-0.35
- Oil yield: 50-60 kg/ha

Varieties:

- **African Marigold**
  - Pusa Narangi Gainda: Orange colour
  - Pusa Basanti Gainda: Sulphur yellow colour
  - Pusa Bahar: Yellow colour
  - MDU-1
  - Cracker Jack
  - Climax: 1st F_1 Hybrid
  - Alaska
  - Fire Glow
  - Golden Jubilee
  - Yellow Fluffy
  - Dusloom
  - Golden Age
  - Nugget: Triploid variety (3x variety)
  - Show Bird

French marigold varieties: Pusa Deep: Maroon colour
Pusa Arpita: Orange colour

- IIHR: Arka Alankara: (yellow colour), Arka Agni (orange colour)
- Pusa Narangi Gainda: popular in south India (grown throughout India), used in poultry industry, food, pharmaceutical and nutraceutical industries
- Nugget is the most recent interspecific triploid hybrid developed in USA
- **French Marigold:** Cupid Yellow, Petite Gold, Yellow Pygmy, Red Brocade, Rusty Red, Butter Scotch, Valencia Sussana, Golden Boy, Star dust
- ***Tagetes tenuifolia*:** Golden Gem, Lulu, Pumila, Ursula
- Red and Gold colour hybrids (African × French marigold) are developed in America

Pest and diseases:

- Red spider mite: Flower bud rot is caused by *Alternaria dianthi*
- Inflorescence blight is caused by *Alternaria zinnae*

5. Chrysanthemum

5. **Glory of East/Queen of the East/National Flower of Japan:** Asteraceae: 2n=36: Origin: Europe & Asia
   - The name chrysanthemum was derived from the Greek words *chrysos* (gold) and *anthemom* (a flower)
   - Grown for two major purposes: cut flowers and potted plants
   - Cut flower chrysanthemum: produce one flower per stem. Disbudded inflorescences to produce incurved, intermediate, reflexed, anemone-centred, single
   - Nondisbudded types: (pompons. sprays, charms) in which several or all flowers on one stem are allowed to develop flowers
   - Chrysanthemums originated from a complex of species that were all hexaploid (2n =6x =54)
   - Floral emblem of the imperial family of Japan
   - Second largest cut flower grown all over the globe
   - Inflorescence botanically known as a capitulum
   - Most chrysanthemums used for year-round flowering are short-day plants
   - Short day plant: Photo sensitive (10 hours day light)
   - Chrysanthemum starts flowering at <13hrs day length
   - Thermozero cultivars are temperature insensitive
   - Thermopositive cultivars do well at high temperature. <15.5°C inhibition of flower formation
   - Thermonegative cultivars need low temperature to develop- flowering. >15.5°C inhibition of flower formation

Temperature requirement for chrysanthemum cultivars: 3 groups

Cultivar	Temperature range for flowering	Flower initiation
Thermo zero	10-27°C	16°C
Thermo positive	16-27°C (Minimum)	27°C (Rapid initiation)
Thermo negative	10-27°C	-

★ Small flowered double Korean types are mostly grown in open field condition
★ In India small flowered varieties are mostly propagated by suckers or stolons
★ Commercial method of propagation: Suckers and terminal cuttings(June)
★ For enhancement of root formation in terminal cuttings: IBA (Seradix) @ 2500

Species:

★ The genus *Chrysanthemum* comprises of 250 spp.

Specific features	Scientific name
Annual chrysanthemum (yellow colour)	*C. multicaule*
Florists' chrysanthemum (Hybrid species)	*C. morifolium*
Most widely grown cut flower type	*C. maximum*
Popularly grown as pot plants (Paris daisy/ Marguerite)	*C. frutescens*
Garland chrysanthemum or crown daisy (annual type, yellow and white flower)	*C. coronarium*
Tri colour chrysanthemum, winter season annual	*C. carinatum*
Grown in temperate regions for making an insecticide called 'Pyrethrum'	*C. cineraraefolim*
Believed to have been involved in the evolution of florists' chrysanthemum	*C. boreale*

★ Indeterminate origin of varieties from: *C. morifolium*
★ Classification based on kind and arrangements of florets into 5 broad groups (National Chrysanthemum Society, England)
★ Most preferred colour for cut flowers: Yellow and white
★ Flowering time:
  - South India: July to January
  - North India: November to January

★ *Sen rin tsukuri* (Japanese word): Japanese style of chrysanthemum culture means growing thousand blooms, geometric shape)
★ *Cascade form* : is trained to give effect of a water fall in blooming stage
★ Anemone and Korean types of chrysanthemum is suitable for cascade form
★ Jaya, Mayur, Modella, Perfecta and Flirt are most suited chrysanthemum varieties for cascade form
★ *Pot mums* means one cuttings is planted in one pot
★ *Ryori Giku*: Yellow flowering
★ Reduction of plant height: B-nine (0.25%) or Phosphone D
★ Most critical technique in formation of a cascade: Pinching

Pinching:

★ Pinching is one of most important operations in chrysanthemum
★ Pinching or stopping is the most essential for small flowered or spray chrysanthemum
★ Main purpose:
  + To reduce the plant height and promote axillary branches
  + Done at 14-21 days after planting or 8-10cm tall plants
★ Soft pinching: By this pinching the top soft tips of the shoot along with 2-3 open leaves are removed;
★ Hard pinching: It means removing a longer portion up to hard shoot.
★ Disbudding and dis-shooting operations: *e.g.* Large flowered or standard and decorative chrysanthemum
★ Disbudding is done at October
★ Dis-shooting: To reduce the number of branches for improving the size and form of the flower
★ SADH @ 2000-4000 ppm applied after disbudding reduces the stem length, produces thicker stem, enhances the flower colour and increases the vase life
★ Most effective biocide for chrysanthemum: Silver nitrate ($AgNO_3$) @
★ An ideal bud opening solution: 8-HQC @ 200 ppm + 2% sucro
★ Modified atmospheric storage co improved the st
★ Pot mums can be stored perature
★ No pinch No stake

Varieties:

☆ **IIHR V**

- ☆ Kirti
- ☆ Ravikiran
- ☆ Pankaj
- ☆ Indira
- ☆ Arka Pink Star
- ☆ Yellow Gold
- ☆ Yellow Star
- ☆ Red Gold
- ☆ Chandrika
- ☆ Usha Kiran
- ☆ Rakhee

★ Nilima: Purple flowers, good for cut flower, vase life of 14 days

☆ **PAU, Ludhiana:** Yellow Delight, Anmol, Winter Queen, Garden Beauty, Autumn Joy Royal Purple Baggi, Birbal Sahni, Punjab gold

☆ **TNAU: CO_1 and CO_2:** Purple coloured **MDU-1:** Sulphur yellow in colour

★ **NBRI, Lucknow: New varieties:**

★ Himanshu, Kaul and Khoshoo

- Shanti
- Y_2K
- Kargil
- Sadbhavana
- Appu
- Bindiya

★ **NBRI Golden Jubilee Year Varieties:** Indiana, Kusum, Little Darling, Mini Jessie

★ **IARI Varieties:** Pusa Anmol, Pusa Ajay, Pusa Centenary

★ Pusa Anmol: yellowish pink flowers (Gamma ray induced mutant of cv. Ajay)

★ Pusa Anmol: Thermo-and photo-insensitive variety that produces three flowers flushes in a year (October-November, February-March and June-July)

★ Pusa Centenary: yellow flowers (Gamma ray induced mutant of cv. Thai Chen Queen)

★ Pusa Anmol is photo and thermo- insensitive and therefore flowers thrice in a year (Oct-Nov, Feb-Mar and May-Jun).

★ Pusa Aditya

★ Standard: Pusa Kesari, Pusa Arunodaya

★ Spray: Pusa Aditya, Pusa Chitraksha, Pusa Sona

★ **Other varieties:** Show Ball, Gul-E-Sahir

6. Hibiscus

6. **Shoe flowers/ China rose:** *Hibiscus rosasinensis*: Malvaceae; 2n=46;

★ **IIHR Varieties:** Anuradha, Ashishwad, Bharat Sundari, Gautamjyoti, Goti, Indira Gandhi, Ratna

★ Intergeneric hybrid: Thilagam: *Hibiscus rosasinensis* × *Malvaviscus arboreus*

★ Improved variety of Chandrika is Punnagai: Highly suitable for home garden purpose

★ CO-3: Hybrid of Yellow sport × Shanti

★ Pruning height should be 1-1½m

★ Commercially propagated by semi-hardwood cuttings Famous Hibiscus breeder in India R.N. Bhatt, M. Virupaksha

★ Related species: Changeable rose: *Hibiscus mutabilis*

7. Gomphrena

7. **Gomphrena/Globe amaranth/Bachelors button:** *Gomphrena globosa Amaranthaceae*

★ Hardy annual flower plant

★ Prefers tropical and subtropical plant

★ Propagation: Seeds

★ Pinching is a common practice followed in Gomphrena

★ Used as a dry flower, loose flower and garland making

D. Cut Flowers

1. Rose
2. Carnation
3. Orchids
4. Anthurium
5. Gladiolus
6. Dahlia
7. Gerbera

1. Rose

1. **Queen of flowers/Perfume of God**: *Rosa spp.* Rosaceae: 2n=2X=14
   - ★ Rose is a versatile plant
   - ★ King of flowers, symbol of love and affection to mankind
   - ★ Top ranking cut flower in the flower trade on the basis of average, production and consumption
   - ★ Asiatic origin species are mostly diploids and Western Species are tetraploids
   - ★ Bourbon rose: British introduced to India
   - ★ Damask rose: Baber introduced to India
   - ★ Rose colour (Anthocyanin pigments):
     - ✦ Orange red to scarlet → Pelargonidin
     - ✦ Crimson to bluish red → Cyanidin
     - ✦ Blue to violet → Delphinidin
     - ✦ Yellow colour → Chalcones
   - ★ Type of fruit: Hips- Rich source of Vitamin-C content (100mg/100g)
   - ★ Fragrance is controlled by polygenes
   - ★ Inheritance of pigments: Additive gene action

Important rose species:

- ★ Miniature rose is called baby rose or fairy rose
- ★ Floribundas also known as hybrid polyanthas
- ★ Bourbon roses is known as reunion roses
- ★ China roses are the ancestor of the present day popular roses

Common name	Scientific name
Yellow rose or Pernet rose	*Rosa foetida*
Cabbage rose	*Rosa centifolia*
Edward rose	*Rosa bourboniana*
Dog rose	*Rosa canina*
Himalayan musk rose	*Rosa brunonii*
Musk rose	*Rosa moschata*
Damask Rose	*Rosa damascena*
Bengal/Monthly/China Rose	*R. chinensis*
Green Rose	*R. chinensis viridiflora*

- ★ Polyanthas: Polyanthas normally produce dwarfish, bearing often immense clusters of small blossoms e.g. Echo, Chatillon rose
- ★ China rose group has long been considered a refuge for "decoratives" as opposed to exhibition roses
- ★ Miniatures: popular baby roses, hardy and suited for pot culture e.g. Puppy Love
- ★ Miniature roses are ideally suited for edging, pots, rockeries or window gardening
- ★ Floribunda roses are most suitable for hedge
- ★ Miniatures and dwarf polyanthas are used for beautifying terraces and balconies
- ★ Thornless cultivars of roses are belongs to category of "Grand Gala group"
- ★ Multiflora rambler (*R. multiflora*) also belongs ramblers group
- ★ Thorn less rose species: *Rosa blanda*
- ★ Ramblers: *R. wichuraiana* is a wide-spreading cluster-flowered climber/groundcover rose from Japan

Rose Group	Parents	Famous varieties
Hybrid Teas (HT)	Hybrid perpetuals × Tea roses	Super Star, Paradise, Peace, First Red
Floribundas	Hybrid teas × Polyanthas	Confetti, Blue Berry Hill, Apricot Gem
Tea roses	*R. chinensis* × *R. gigantean*	Anna Ol… …ngdon
Grandifloras	Floribundas × Hybrid Te…	Quee…
Damask Roses	*R. gallica* × *R. Ph…*	C…
Albas	*R. corymbife…*	

Noisette Roses	*R. chinensis* × *R. moschata*	Lamarque
Austrian Briars	Main source of modern yellow roses	Austrian yellow, Persian Yellow
Rugosas (*R. rugosa*)	Thorny Japanese rose	Pink grootendorst
Bourbon Roses	'Parsons' Pink' × Damask Perpetual	Edouard rose
Moss Rose	Mutations or "sports" of centifolias	

Propagation:

- ★ Optimum temperature for cultivation of rose: 15.5°C
- ★ Growth regulators: IBA/NAA improves rooting
- ★ Season for raising cuttings: June-November
- ★ Best rooting media for rose : Sand
- ★ Ideal time for budding in Northern Plains: December to February
- ★ Ideal temperature for bud union: 10-25°C
- ★ Bud union takes place in 3-4 weeks
- ★ Ideal time for planting in Northern Plains: Mid-October

Group	Propagation
Commercial method of propagation	'T'budding
Miniature roses	Semi-hard or hard wood stem cuttings
Climbers, Ramblers and Polyanthas roses	Stem cuttings
Hybrid Tea and Floribunda roses	T-budding
Rootstocks of roses used in India	Stem cuttings
R. nitida, R. blanda, R. virginiana	Root cuttings

cks:

Purpose	Rootstocks
r rose rootstock in North India, Tolerant lery mildew and high soil pH	*Rosa indica* var. *odorata*
rootstock used in coastal areas	*Rosa multiflora*
rootstock is Edouard rose	*Rosa involucrata or Rosa indica* in Northern Plains

Resistant to drought and heavy soils	*Rosa canina*
Nematode resistant and vigorous	*Rosa multiflora*
Heat resistant	*Rosa clinophylla* and *Rosa bracteata*
Cold resistant	*Rosa rugosa*
Triploid species	*Rosa clinophylla*

Pruning type:

Groups	Pruning type
Hybrid Teas	Hard pruning
Floribundas	Moderate-light pruning
Polyanthas	Little or no pruning
Miniatures/climbers/ramblers	No pruning

Pruning time:

Rose	2 or 3rd week of October
R. damascena (Perfume purpose)	December to mid-January
Tamil Nadu	End of Nov- Early Dec. Hills: Mar-Apr.
Bangalore	End of June and End of Nov.
South India	Pruning is done twice a year
North Indian hills	Oct-Nov
For commercial purpose: Staggered pruning	23rd Sep-16th Oct

Special practices:

- ★ Wintering (Root pruning) practice is followed for early flowering in Pune region of Maharashtra
- ★ After root pruning it takes 45 days to flower
- ★ Pinching: Removal of terminal growing portions and is mainly done to reduce the plant height and encourage lateral branching
- ★ Disbudding: Undesirable bud is removed keeping only the central bud intact
- ★ Deshooting: Mainly done in Hybrid Teas (HTs) and increases the yield to 50-75%
- ★ Defoliation is the removal of leaves during pinching manually/using chemicals for improves the flower production

★ Bending is done in 3 months old plants, to induce the new sprouts (Balance between source and sink)

★ Bud capping: Bud caps are placed on the flower bud at pea size. Increase the bud size and shape

Harvesting stages:

★ Cut flowers for local markets → harvested when the outer petals start curling outwards

★ For distant markets →'tight bud stage' with buds showing full but petals not unfolded

★ Loose flowers→ harvested when fully open

★ Rose essential oil (otto of roses) is extracted by steam distillation

★ Rose flower essential oil content: 0.02-0.05%

★ The important oil yielding rose species: *Rosa damascena*, *R. bourboniana*, *Rosa centifolia*, *R. alba* and *R. galliaca*.

★ In India, *R. damascena* and *R. bourboniana* are cultivated for rose oil

★ Bulgaria is the major producer and exporter of 'otto of roses'.

★ Most suitable species used for essential oil extraction (maximum oil yield): *R. damascena* (0.057-0.058%)

★ Modern oil bearing damask rose: *R. damascena* Trigintipetala

★ From 4000 kg of petals 1 kg of rose oil is obtained

★ Essential oil is a generic term applied to all aromatic products, such as essence oils, absolutes, resinoids, and concretes

★ Enfleurage is usually practiced to extract oil from delicate flowers, such as rose, jasmine

★ Main composition of rose oil: Citronellol and geraniol

★ Bulgarian rose oil is recognized as the 'ultimate best rose oil' in the world

★ Rose water: Water distillation of rose petals

★ Rose gulkhand is prepared a mixture of rose petals with white sugar in a equal proportions (1:1)

★ Rose gulkhand used as a tonic and laxative

★ Edward rose is mainly used for making gulkhand

★ Dried rose petals are called 'Pankhuri', mainly used for preparing cool drinks

★ Optimum yield of cut rose:

- ✦ Green house: 150-200 stems/m^2/year
- ✦ Loose flowers: 3-5 tonnes/ha/year

★ Cut roses minimum vase life: 12 days

★ International Registration Authority of Roses (IRAR) is located at USA

★ National Registration Authority of Roses (NRAR) is located at New Delhi

★ The Rose Society of India located at New Delhi

★ Asia largest rose garden: Zakir Hussain Rose garden is located Chandigarh, Haryana

★ 1st Hybrid Tea rose 'La France' was developed by Guillot in France in 1867

★ 1st Yellow Pernet rose was developed by Pernet- Drucher

★ 1st Polyantha rose: La Paquerette (1875)

★ 1st recorded rose perfume is in Charaka Sanghita

★ 1st rose variety released in India: Dr. S.D. Mukerjee in 1935, B.K. Roy Choudhary, West Bengal

★ 1st rose variety of Dr. B.P. Pal (IARI): Rose Sherbet in 1962

★ Pioneer rose breeder in India: B.S.Bhattachajee

★ Scientific rose breeding in India: Dr. B.P.Pal, 1958

★ "Rose in India" book written by Dr. B.P.Pal

★ "Survey of Rose Breeding" in India book written by Dr. B.P.Pal

★ Total Number of species in rose: 120

★ Generally accepted classification of roses is Rehder

Pest and diseases:

★ Serious pest of rose: Red Scale (*Anidellia aurantii*)

★ Die back (*Diplodia roseum*) is very serious disease of roses and appears after pruning

★ Black spot (*Diplocarpon rosae*)

★ Powdery mildew (*Sphaerotheca pannosa* var. *rosea*)

★ Rose wilt is caused by virus (Aphids)

Varieties:

★ **Important rose breeder in India:** B.P.Bal, S.C.Dey, J.P.Agarwal, A.P.Singh

★ **IARI varieties:**

- ✦ Pusa Shatabdi
- ✦ Pusa Mohit: Thornless variety
- ✦ Pusa Komal
- ✦ Pusa Christina
- ✦ Pusa Ajay
- ✦ Pusa Arun
- ✦ Pusa Ranjana
- ✦ Pusa Abhishek

★ **Hybrid Teas:**

- ✦ Pusa Bahadur, Pusa Mahak
- ✦ Pusa Gaurav
- ✦ Pusa Garima
- ✦ Pusa Priya

★ **Floribundas varieties:**

- ✦ Pusa Barahamasi: Tolerant to dieback, powdery mildew and black spot
- ✦ Pusa Pitamber (Jantar Mantar × Banjaran): Tolerant to powdery mildew and black spot
- ✦ Pusa Virangana

★ Fragrance rose cultivars selected by Department of post for unique stamps: 4 varieties: 2007
- First postal stamp variety: Mrinalini
- Unique scented postal stamps IARI: varieties: Delhi Princess, Bhim, Jawahar

★ F1 hybrid roses:
- Pusa Arunima, Pusa Chandrana, Pusa Prema

Specific features:

★ Induced mutation variety in IARI, New Delhi: Abhisarika, Pusa Christiana, Madhosh
★ Loose flower production rose: Neelambari and Arunima
★ Banjaran: best for garden display
★ Exotic cut flower varieties in Pune regions: Skyline, Nobelesse and Golden Gat
★ Gladiator is very popular variety among rose growers of Nasik and Pune (Open condition)
★ Chocolate brown colour patented in variety: Mohini (Aneuploidy)
★ Hyper triploid (2n=22): Mohini
★ Highly fragrant rose variety: Rose Sherbet
★ Major promising exotic varieties: Skyline, Nobeless, Golden gate
★ Cut flower variety: Pusa Gaurav
★ Suitable for loose flower production: Neelambari, Arunima
★ Cultivars suited for bush rose: Christian Dior, Double delight, First prize, Superstar
★ Varieties suitable for rockeries: Fairy Queen and Magic
★ Fragrant greenhouse cultivars: Jacaranda, Cocktail, Konfetti

Class	Indian varieties	Foreign varieties
Hybrid Teas	Poornima, Priyadarshini, Abhisarika, Abhaya, Pusa Sonia	Super Star, First Prize
Floribundas	Banjaran, Kum Kum, Arunima, Mohini, Suryakiran	Play boy, Confetti, Summer Snow
Miniature	Pushkala, Chandrika, Chunmun, Delhi Starlet	Galkaxy, Rise and Shine
Polyanthas	Barani, Priti, Anjali, Rashmi	May Wonder, Pink showers
Climbers	Climbing Ramba, Climbing Matangi	Show Garden

Green house rose:

★ Suitable green house for tropical regions: Saw tooth design
★ High temperature in poly house: Reduced by application of lime on top
★ Cooling system used: Fan and pad system

★ Optimum temperature for bud sprouting: 18°C

Colour	Variety
Red colour	Grand Gala, First Red
Pink colour	Kiss, Nobles, Sonia
Orange colour	Mercedes
Purple colour	Jacaranda, Souvenir
Yellow colour	Golden Time, Frisco, Golden Gate
Bicolour	Amour, Confetti, Rodeo
Bronze	Safari

★ Bent neck: Too early maturity
★ Blackening of petals is due to low temperature or high temperature
★ Average yield: 150-300 flower/m^2

2. Carnation

2. **Carnation/Divine flower/Garden pink**: *Dianthus caryophyllus*: Caryophyllaceae: 2n=2X=30: Origin: Southern France

★ Dianthus in Greek means Divine flower
★ Cool season crop
★ Herbaceous half hardy perennial flowering plant
★ Carnation is a quantitatively long day plant (needs 21.5k lux for at least 8hr in a day)
★ First introduced carnation into India: 1980 (Sim type of carnations)
★ Present day modern carnation originated from Sim cultivar group
★ Ideal conditions for round-the-year cultivation of carnation.: Tamil Nadu hills and mid hills of Himachal Pradesh
★ Optimum temperature for standard carnation: 18 to 23°C
★ Optimum temperature for quality flower production: 10-12°C
★ Carnation minimum light intensity: 21.5 klx (2000 foot-candles)
★ North Indian plains, carnation plants need shade nets with 25-50% to get quality flower
★ Type of inflorescence: Spike
★ Pinks carnation: *D. plumarius*
★ Chinese and Indian Pinks have come from *D. chinensis*: Origin: China
★ Standard carnation means o... ...on a si... ...le cultivation
★ More demand in India...

★ Spray carnation means with several smaller flowers per stem-popular in USA

Pigments in flower:

Groups	Colour
Acyanic group	White, Yellow
Cyanic group	Red, Salmon. Lavender, Pink
Transition group	Crimson

★ Sweet William: *D. barbatus* : Commercially grown for seeds

★ 1st interspecific hybrid developed in the world by Thomas Fairchild (1717): Carnation × Sweet William

★ Carnation classified into 4 classes

Chabaud/marguerite	Border or Picotee	Malmaison	Perpetual carnation
Annual	Bushy type	Massive habit	Cut flower type
Seed propagation	Symmetrical flower	Fragrance flowers	Better quality
Fused petals			
Low shelf life			

Commercial carnation species:

Carnation types	Originated/Derived from
Perpetual carnation	*D. caryophyllus* × *D. chinensis*
Marguerite carnation	*D. chinensis* × *D. caryophyllus*
Royal carnation	Malmaison × Perpetual carnation
Malmaision types	Seedlings of perpetual carnation
Yellow carnation	*D. knappi* (2n=30)
White carnation	*D. plumarus* (2n=90)
Indian pink/ Chinese pink	*Dianthus chinensis* (2n=4X=60) (Japanese pink)
Either tetraploid/hexaploid	*Dianthus gratianoplitanus* (2n=90)

★ Major work of carnation improvement: USA and France

★ Pioneer carnation breeder: Montague Allwood

★ Popular carnation type in India: Clove scented marguerite carnation

★ Marguerite type of carnation is generally grown as a winter annual

★ Spray carnations can tolerate slightly warmer temperature

★ Perpetual carnation stamens are transformed into petaloids

★ Singleness flower is controlled by incomplete recessive gene

★ Doubleness flower is controlled by monogenic dominant gene

Propagation:

★ Margurite/annual carnation is propagated by seeds

★ Perpetual/perennial carnation is propagated through terminal stem cuttings (8-10 cm long with 4-10 cm long with 4-6 leaf pairs)

★ For enhancement of root formation in cuttings: NAA @ 500 ppm (Quick tip method)

★ Seed propagation types: Marguerite and Chabaud types

★ Spacing: Standard carnation: 20 cm × 20 cm; Spray carnation 30 cm × 30 cm

Special practices:

★ Green house direction (Length): North-South

★ Green house gutter direction: North-South, Polythene thickness: 200microns

★ Carnation crop needs to be supported with 4 or 5 layers of support material

★ Best support material is metal wire

★ Unpinched, this main stem produces flower called "Crown flower

Pinching or stopping

- An important operation in the successful production of quality carnation. Remove the head of this main stem at an early stage. Enhances the more number of side shoots
- Pinching should be done below 6th node
- Single pinching method: for getting early crop
- Pinch and a half: continuous production flowers

Disbudding

- Removing undesirable immature flower buds (5-10 mm)to provide either large flowers
- Spray or miniature type carnation: central terminal bud is removed. Encourage lateral flower buds to develop
- Standard carnations: side buds removed to give main flower a chance to develop

✦ **Netting:** Done at vegetative growth occupied in the middle ... rowing into the path have to be tucked back into ...

✦ Preconditioning of cut flowers in ... practice to avoid ethylene injury and prolo...

✦ Carnation produce cut bloo...

Pest and diseases:

- Red spider mite (*Tetranychus urliticae)* is a serious pest during hot months and dry period
- Most common and devastative disease: Fusarium wilt (*Fusarium oxysporium* f. sp. *dianthi*)
- Flower blight (*Botrytis cinarea*)
- Stem rot (*Rhizoctonia spp.)*

Physiological disorder in carnation:

- Calyx splitting is very common in double carnation
  - Factors: Genetical, nutritional, environmental and genetical factors
  - Low temperature (<10°C), low N_2, high ammonical N_2 and low boron level
- Sleepiness disorder is due to production of high ethylene/high stress
- Curly tip disorder is due to low temperature, low light and N_2 deficiency
- Slab side is type of malformation during cool periods

★ Storage temperature: 4 to 6°C
★ Carnation is highly sensitive to ethylene
★ Ideal stage for harvest:
  - Long distance transport → Paint brush stage
  - Short distance transport → Semi-open stage

★ Tinting process is done in carnation
★ Tinting means application of artificial colour in white coloured carnation flower
★ Enhancement of shelf life by silencing genes of ACC oxidase and ACC synthase

Varieties:

★ **IIHR Varieties:** 1. Arka Flame: Tolerant to Fusarium wilt and nematodes
2. Arka Tejas

★ **Suitable varieties for greenhouse condition:**
  - **White:** White Sim
  - **Pink:** Pink Sim
  - **Scarlet:** William Sim, King Cardinal
  - **Yellow:** King Midas, Golden Wonder

★ **Two-toned varieties:** Dairymaid, Eastern Wonder, Pelargonium, Peppermint
★ Tetraploid cultivars: Sarafi and Mabdavian (2n=60)
★ Recently developed variety: Pico
★ Longest shelf life cultivar: Roland
★ Resistant to *Fusarium* wilt: Arbel and Scarlette
★ Transgenic carnation: Florigene company: Transgenic variety: Moon dust : Colour: Violet Purple
★ Transgene for better rooting ability: *rol C* gene

3. Orchids

Orchids: Orchidaceae

★ India is native to number of orchids which are found in abundance in North Eastern Hilly region
★ Indian origin orchids: Cymbidium, Dendrobium and Paphiopedilum
★ Top ten cut flowers, orchids rank sixth position
★ Among orchids Cymbidium ranks the first position and in floricultural crops it accounts for 3% of the total cut flower production
★ India accounts for nearly 7% of worlds orchid biodiversity contributing 1300 species
★ 80% are cut orchids, and the remaining 20% is composed of pot plants
★ The Netherlands is the largest exporter (39. 67%) of orchids in the world
★ National Research Centre for Orchids (NRCO) located at Pakyong, Sikkim
★ Thailand is the largest world exporters of tropical orchids
★ Most of the orchids are day neutral
★ Orchids are climate specific crop
★ World largest importer of orchids: Japan
★ World largest exporter of orchids: Thailand
★ Orchid flower contains 7 parts: 3 sepals, 3 petals and 1 gynostemium or column
★ Specific feature of orchid flower: Both petals and sepals are coloured
★ 1st artificial orchid hybrid: *Clanthe dominy* developed by John Dominy
★ Cymbidium (Temperate orchid) is now among the top 10 cut flowers of the world market
★ Most widely cultivated tropical orchid: Dendrobium
★ Large number of species among orchids: Dendrobium (over1000)
★ Monarchy of orchid in the world: Paphiopedilum
★ Most popular cut flower orchid in Asia: Dendrobium
★ Commercial orchids grown in India are epiphytic
★ Temperate zone: Terrestrial orchids
★ Tropical zone: Epiphytic orchids
★ Sympodial orchids produce swollen stems (Pseudobulbs) to store water and the food material
★ Sympodial orchids: Multi stemmed
★ Monopodial orchids
  - Produces a single co
  - P
  -

★ Intergeneric monopodial hybrids: Aranda, Assocenda and Mokaro
★ Among the sympodial orchids, major share on area is Dendrobium and its hybrids

Cymbidiums

- Most popular winter and spring blooming
- Semi-terrestrial orchids
- Origin: tropical and subtropical Asia

Dendrobium

- Potted plants and cut flowers (floriferousness)
- Year round availability and lengthy vase life
- Most dominant crop in tropical orchid

Classification of orchids:

Growing habits	Orchids
Monopodial orchids	Vanda, Vanilla, Aerides, Phalaenopsis, Arachnis and Aranda
Sympodial orchids	Dendrobium, Cymbidium, Bulbophyllum, Oncidium, Cattleya, Epidendrum
Epiphytic orchids	Dendrobium, Vanda, Bulbophyllum and Obernia
Tropical orchids	Vanda, Dendrobium, Mokara, Oncidium

★ **Epiphytic orchids:**

- Epiphytic orchids usually grow on tree trunks or branches
- Thick leaves and succulent stems have CAM and are drought tolerant with higher water use efficiency e.g. Dendrobium, Cattleya

★ **Rhizomatous orchids:** requires terrestrial climate e.g. Habenaria, Eulophia
★ Main characteristic of the orhids is the layer of spongy tissue, known as 'velamen' around the true root
★ Velamen tissue is a highly specialized organ facilitates the absorption of water and mineral salts
★ Velamen common feature of epiphytic orchids
★ Column (or) gynostemium, situated in the centre of the flower, is the unique structure of orchids distinguishing them from other flowers
★ Gynostemium or column is formed by fusion of male (anthers) and female part (Gynoesium)
★ Stamens and style fuses to form a column or gynodrium or gynostemium
★ Modified tapel of orchids is known as lip or labium
★ Pollen in orchids is generally waxy masses known as pollinia (2-8)
★ Critical determining factor for in the genera of orchid family: "Pollinia"

★ Type of inflorescence in orchid: Simple raceme or spike or branched panicle (Bisexual flowers)
★ Type of orchid fruit: Capsule
★ Pollination: Insects
★ No. seeds ranges per capsule: 50000 to 60000

Important orchids:

★ First orchid *Bletia purpurea* (1731) was grown by Peter Collinson who was the 1st among the westners to grown an orchid

Common Name	*Genus*
Tiny orchid (no leaves and stem)	*Taeniophyllum khasianum*
First largest genus of orchids	Bulbophyllum
Second largest genus	Dendrobium
Largest Indian orchid	*Galelola falconesi*
Smallest Indian orchid	*Eria pusilla* (1cm)
Climbing orchid	Arachnis and Vanda
scorpion orchid/spider orchid	Arachnis
sun loving orchid	Renanthera
Lady's slippers	Paphiopedilum
Dancing lady	
Spider orchi	
Butterflie	
Moth o	
Dov	aenopsis
Fo	Peristeria
	Rynchostylis
	Vanill

★ Original source of commercial vanillin: *Vanilla planifolia*
★ The drug *chin shih hu* obtained from dried stem of *Dendrobium nobile* is being used in China as antipyretic and tonic

Optimum temperature for orchids

Type of orchid	Temperature range	Night temperature	Examples
Cool orchid	15.5-21°C	10-12.5°C	Cymbidium
Warm orchid	21-29°C	15.5-18°C	Vanda, Phalaenopsis, Dendrobium
Intermediate orchid	18-21°C	15.5-21°C	Cattleya

★ Ideal for the growth of most of the tropical orchids: Humid and warm atmosphere
★ Orchid prefers high humidity: 75-80%
★ Orchid seeds is non-endospermic in nature
★ Optimum temperature for seed germination: 20-25°C
★ Pre-treatment of seeds: Sodium hypochlorite (2.6%)
★ Repotting is done at active vegetative growth stage
★ Orchid germination media: Knudson media
★ Common media for epiphytic orchids: Osmunda

Propagation:

★ Sympodial orchids are commercially propagated by division
★ Monopodial orchids are commercially propagated by top cuttings

Propagation methods	Examples
Air-layering	Vanda
Flower stalk cuttings	*Phalaenopsis, Phaius*
Cuttings	*Vanda, Arachnis, Ascocentrum*
Off-Shoots (Keikis)	*Dendrobium, Phalaenopsis, Paphiopedilum*
Division (Most suitable for sympodial orchids)	*Dendrobium, Cattleya, Epidendrum, Oncidium*

★ Off-Shoots are miniature plants with roots from the nodes of old canes
★ The shoots growing on the plants of orchids are called Keikis
★ Keikis is more common in Dendrobium
★ Keikis (Shoot): Produced from node region

★ Pseduobulb is a secondary stem modification
★ Unique structure of orchid flower: Column or gynostemium
★ Long spikes orchids: *Dendrobium, Phalaenopsis, Aranda, Arachnis*
★ Orchid flowers are stored at 5-7°C
★ Storage temperature below 7°C causes chilling injury to the flowers
★ Major pest: Snails and slugs
★ Effective control agent for snails and slugs: Metaldhyde
★ Major disease: Heart rot (*Phytophthora*)

Common name	Scientific name	Related Genera	Varieties
Scorpion orchid	Arachnis	Renanthera	Red Ribbon, Yellow Ribbon
	Vanda	Aerids and Rhyncostylis	Ruby Prince, John Clubb
Moth orchid	Phalaenopsis	Doritis	Rose Parade, Temple Cloud, Diana Pinky
Dancing girl orchid	Oncidium		Goldiana, Gower Ramsey
	Cattleya	Brassavola, Laelia	Edithe Bow Bells, Suzanne Hye

Varieties:

Types	Varieties
Dendrobium	Emma white, Sonia 17, Sonia 28, New pink, Pink tips, Candy stripe
Cymbidium	Peterpan, Promona
Phalaenopsis	Texas Star, Violet Mist
Vanda	Evening glow, Honolulu
Cattleya	White Christmas, Estelle
Oncidium	Tiny Tim, St. Anne, Golden shower

4. Anthurium

4. **Anthurium:** *Anthurium spp.* Araceae: 2n=2X=30: Origin: Colombia
★ Tropical, semi terrestrial and perennial herbaceous pla
★ 2nd cut flower among the tropical cut flowers
★ Anthurium is a *Greek* word (*Anth*

★ Anthurium is divided into 4 groups
★ Economic part: Spathe
★ Major exporter of anthurium: Netherlands
★ Flowers are protogynous in nature
★ Type of inflorescence: Spadix
★ Type of pollination: Cross-pollination
★ Pollinators: Bees
★ Type of fruit: Berry
★ The flowers consist of a colour full modified leaf called the 'spathe'
★ Spadix is commonly known as 'candle'
★ The spadix or the inflorescence contains 50 to 200 flowers
★ Spathe growth: Double sigmoid growth curve
★ Most preferred colour of the spathe is "Red" followed by pink
★ Dwarf species currently referred to as andreacola types
★ Anthurium colour pink to dark red is due to cyanidin and coral to orange is due to pelargonidin
★ Anthurium bloom throughout the year, one bloom arising from the axil of each leaf

Important species:

★ Flowering species: *Anthurium andreanum, A. browni, A. schesianum*
★ Foliage species: *A. corrugatum* and *A. crystalenlum*
★ 1st widely cultivated Anthurium pot plant: *Anthurium scherzerianum* (Foliage anthurium)
★ *Anthurium andraeanum:* 2n=30: commercially cultivated for cut flower production
★ *Anthurium andraeanum* is a secondary polyploid
★ Flamingo flower/Flame plant (*Anthurium scherzerianum*): Commonly used as potted plant
★ *A. scherzerianum* × *A. wendlingerii*: Production of greyish orange spathe
★ More suitable for commercial cultivation of anthurium: High temperature, Low RH and low cost polyhouses
★ Temperature require for initiation of flowering: 18°-24°C
★ Optimum temperature for vegetative growth: 18.3°C
★ Hybrid anthurium cultivar grow in high temperature (30°C)
★ Leaf soorching is common when temperature exceeds 35°C and high RH
★ Ideal RH for anthurium: 80%
★ Shade requirement for anthurium: 60-80%
★ Ideal shade for their healthy growth: 75%
★ Advisable shade in commercial practice: 50% shade on the top and 25% shade net below

★ Enrichment of CO_2 induce the vegetative growth (900 ml/m^3)
★ Summer month needs 80% shade and light intensity: 2000-3000 lux
★ Suitable species for potted plants or grown in pots: *Anthurium scherzerianum*- Miniature type
★ Optimum spacing for commercial cultivation of anthurium: 45cm × 45 cm (5 plants/m^2)
★ Anthurium starts producing suckers once they attain an age of 12-16 months
★ Suckering capacity can be improved by application of BAP @ 75 ppm at monthly interval
★ To production of high number quality of flowers and highest number of suckers per plant: 31:10:10 NPK @ 0.2% + GA_3
★ To delaying of spadix necrosis, spathe blueing and longest vase life: BA @25 ppm +8-HQC @ 30ppm
★ Stage of harvest: Spathes completely unfurl and well developed spadix, development of true flowers on spathe
★ Leaf pruning and deoffshooting is the commercial practice to enhance the quality of flowers
★ Angle between spathe and spadix should not exceed 45°
★ Yield: 8-12 flowers/plant/year
★ Harvesting maturity: Unfolding of the spathe is complete
★ The optimum storage temperature for anthurium is 14-17°C
★ The longevity of the spathe on the plant varies from 60-90 days
★ The standard, upright and heart shaped spathe are mostly preferred in the markets

Pest and diseases:

★ Most serious disease: Anthracnose/Spadix rot/Black nose (*Colletotrichum gleoesporidoes*)
★ Major problem in anthurium: Bacterial diseases (*Pseudomonas solanacerum*)
★ Source of bacterial disease resistance: *Anthurium antiquiense*
★ Colour break in spathes is due to calcium deficiency
★ To stabilize the spathe colour: Application of lime or $CaNO_3$ @ 5 g/plant

Important Varieties:

★ Temptation, Leema White, Honduras, B-13, Sunset Orange, Sun-Shine Orange, Meringue, Glamour
★ Agnihotri, Candy Queen, Nitta
★ New interspecific hybrid: Anthurium × Red Hot
★ Floriferous interspecific hybrid: Anthurium cv. Showbiz
★ Clonal selection variety: Uniwon, Marian Seaforth
★ All day fragrance variety: T
★ Bicoloured spathe: Ob
★ Green col
★ M

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5. Gladiolus

5. **Sword lily/Corn Flag**: Iridaceae: 2n=30: Origin: South Africa
   - ★ Queen of bulbous flowers
   - ★ Gladiolus name from the *latin* word 'Gladius" means 'Sword like" because of sword like shape of its foliage
   - ★ 4th rank in International cut flower market
   - ★ Leading cut flower of India as well as world
   - ★ Prefers open sunny condition for cultivation
   - ★ On the basis of their geographical origin *Gladiolus sp*. 4 groups
   - ★ Modern types of gladioli are classified into 6 types on the basis of plant height, flower size and arrangement on the spike
   - ★ Commercial propagation: Corms
   - ★ Corms size: 4-5 cm diameter
   - ★ Corms are then packed in crates or in net bags and stored at cold storage 3-7°C
   - ★ Breaking corm dormancy: treating with Ethylene chlorohydrin or Ethrel (1000 ppm) or gibberellic acid (100-500 ppm)
   - ★ Curing is one of the essential post harvest operations for successful storage of corms
   - ★ Corms curing done at 21°C for five weeks
   - ★ Descaling also stimulates germination of dormant cormels
   - ★ Planting time: November
   - ★ Planting corm depth: 30 cm deep
   - ★ Yield: 30 x 20 cm spacing provides yield 1,50,000 marketable spikes per hectare
   - ★ Vase-life of gladiolus spikes varies from 5-10 days
   - ★ Corms and cormels are ready for lifting from the ground 6-8 weeks after harvesting of spikes.
   - ★ Commercial life of any gladiolus variety:10-15 years
   - ★ Gladiolus planted at a spacing of 30 x 20 cm yields approximately 1,50,000 marketable spikes per hectare
   - ★ Flower bud initiation starts when the plant is at 3 leaf stage
   - ★ Gladiolus is an indicator plant for fluoride pollution (symptoms: leaf scorching appear drying of tip of leaves)
   - ★ Fluoride injury reduced by spraying of Lime 5% or Magnesium sulphate
   - ★ **Important gladiolus breeder in India**:
     - o Bajrang Bahadur Singh Bhandari, R.L.Mishra, S.S.Negi, D.Mukherjee

- ★ **New IARI Varieties:** Pusa Unnati, Pusa Srijana, Pusa Red Valentine, Pusa Sarang, Pusa Shingarika, Pusa Shubham, Pusa Kiran, Pusa Manmohak, Pusa Subagin, Pusa Bindiya, Pusa Gundjan, Pusa Kamini, Pusa Sukangn, Pusa Swapnil, Pusa Shweta, Pusa Swarnima
- ★ **PAU new varieties:** Punjab Flame, Punjab Elegance, Punjab Lemon Delight and Punjab Glance
- ★ **Varieties:** Friendship, Priscilla, Show Princess
- ★ **New variety:** Arka Aayush, Arka Manorama
  - ☆ **Shobha**: Mutant developed from *wild rose* by irradiation
  - ☆ **Peter pears**: Mid-season cultivar
  - ☆ **Nazrana**: Hybrid between Black Jack × Friendship

Cultivars of great demand in International cut flower trade:
- ★ Priscilla, Peter Pears, White Friendship, Hunting Song, Nova Lux

Important varieties released by various institutes:

Institute	Varieties
IARI, New Delhi	Agnirekha, Mayur, Suchitra, Neelam, Anchali, Archana, Bindiya, Shweta, Vandana, Chandini, Kamini, Mohini, Sukanya
IIHR, Bangalore	Arka Amar, Arka Gold, Arka Naveen, Kum Kum Aarti, Aguara, Kum Kum, Nazrana, Poonam, Sapna, Shoba, Sindu
NBRI, Lucknow	Archana, Arun, Hans, Indrani, Kalima, Kohra, Manohar, Manisha, Mohini, Mridula, Mukra, Priyadarshini, Sada bahar, Smita
PAU, Ludhiana	Punjab Dawn, Punjab Morning, Shan-e-Punjab

Colour of important varieties

Colour	Varieties
Pink	Applause, Friendship, My love
Orange	Autumn Gold, Coral Seas
Red	Black Prince, Hunting Song, Oscar, Victoria
Yellow	Folk Song, Golden Harvest, Golden Peach
White	Friendship
Purple, Violets	Pusa Sarang, Pusa Shingarika, Blue Moon, Mayur

Pest and disease

6. Dahlia

6. **King of flowers:** *Dahlia variabilis*: Asteraceae: Origin: Mexico
   - ★ Dahlia are deciduous, tuberous-rooted hardy perennials
   - ★ Cultivated dahlia is tetraploid (n=32)
   - ★ Facultative short day to day neutral plant
   - ★ Dahlia 1st introduced in India: 1857 Agri-horticultural society of India, Kolkata
   - ★ Yellow colour in dahlia → Chalcones and Aurones
   - ★ Largest producer of tuberous rooted dahlia: Netherlands
   - ★ Common popular Dahlia in India: Giant decorative
   - ★ The National Dahlia Society of England has classified Dahlias into 10 groups
   - ★ Preferred photoperiod: 12-14hrs day length
   - ★ Commercial propagation: Terminal stem cuttings
   - ★ Dahlia is propagation by seeds, tuberous roots and cuttings
   - ★ Planting time: North India: September to December South India: May-June

Important species:

Name	Species	Features
Tree Dahlia	*D. imperialis*	White with red tinged flowers
Cactus Dahlia	*D. juarezi*	Scarlet flowers
Ancestor of dahlia	*D. variabilis*- the garden type	Octoploid species; Self incompatible
Highly variable species	*D. coccinea*	Single red flowers
-	*D. merckii*	Lilac and yellow flowers

- ★ Self incompatibility is major problem in breeding
- ★ To induce flowering in dahlia: GA_3@100 ppm
- ★ Reduction of plant height: CCC, MH
- ★ Disbudding is done at "pea stage"
- ★ Major air pollutant to dahlia: Sulphur dioxide (SO_2)
- ★ Ideal temperature for tuber storage: 4-7°C
- ★ Satisfactory method of flower preservation: Late cutting
- ★ Important breeder in Dahlia: Swami Vinayanda, P.K.Das, A.K.Dey
- ★ **Decorative varieties:**
  - o Bappaditya, Glory of India, Nearest blue, Pranati, Nirmal Chandra, Prabhujee, Prime Minister

- ★ Sectorial chimera mutant: Manalai
- ★ Natural mutant cultivar: Junita
- ★ Multiple flower mutant cultivar developed by Broertjes and Banner (Holland) and through tuber irradiation (gamma irradiation 8Kr)
- ★ Major disease: Powdery mildew (*Erysiphe polygoni*)

7. Gerbera

7. **Transvaal Daisy/Barberton Daisy/African Daisy**: *Gerbera spp.*; Asteraceae; 2n=50; Origin: South Africa
   - ★ Stemless perennial herb, cold sensitive with mono and double flowering types
   - ★ Sensitive to salt
   - ★ Choice crop for polyhouse cultivation
   - ★ Leading cut flower in India
   - ★ Gerbera was 1st discovered in 1878 in South Africa by Botanist "R. Jameson"
   - ★ Famous gerbera breeder: R.Z.Lynch
   - ★ Best species which is commonly grown in the garden: *Gerbera jamesonii*
   - ★ Present day cultivars originated from *Gerbera hybrida*: *G. jamesonii* × *G. viridifolia*
   - ★ Himalayan gerbera: *Gerbera kimziana*
   - ★ Potted gerberas are commonly called as Samurai
   - ★ Type of inflorescence: Capitulum (Protogynous)
   - ★ Optimum temperature for gerbera cultivation: 25-27°C
   - ★ Optimum night temperature for gerbera: 12°C
   - ★ Optimum pH for quality flower production: < 5
   - ★ pH: 5-7.2 produces long flower and stem
   - ★ Propagation: Division of clump, cuttings taken from leaf axillary bud, tissue culture
   - ★ EMS is the best mutagen for single gene mutation induction in seeds
   - ★ Optimum planting time: June-July
   - ★ Gerbera flower has longer shelf life

Varieties:

- ★ **Popular varieties:** Sunset, Nevada, Sangna, Vino, Venturi, Gold Spot, YCD-1 and YCD-2
- ★ **IIHR Varieties:** Arka Krishika: Suitable for open conditions
- ★ New varieties: Arka [illegible] and Arka Nes[illegible]
- ★ Highest yiel[illegible]
- ★ M/S Ter[illegible]
- ★ Some[illegible]

Problems in gerbera:

- ★ Serious pest in gerbera: Leaf miner (*Liriomyza trifoli*)
- ★ Major disease in green house condition: Foot rot (*Phytopthora cryptogea*)
- ★ Stem break is a disorder: 10cm below the capitulum (flower stem not fully developed)
- ★ Stem break is the post harvest disorder due to lead (Pb) deficiency
- ★ Higher pH leads to chlorosis

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CPK

E. Speciality Flowers

1. China aster	2. Alstroemeria
3. Day lily	4. Gypsophila
5. Stock	6. Lotus
7. Bougainvillea	8. Bird of Paradise
9. Heliconia	10. Petunia
11. Amaryllis	12. Gaillardia
13. Zinnia	14. Calla Lily
15. Statice	16. Lilum

1. China Aster

1. China Aster: *Callistephus chinensis*; 2n=2X=18: Origin: China Family: Asteraceae
   - ★ Most popular among the annuals
   - ★ Comet types: (Quilled flowers) 1886
   - ★ Non-branching types: James Vick, 1893, USA
   - ★ Classified into 3 groups
   - ★ Flower colour: Multiple colours
   - ★ Self pollinated crop (Geitonogamous)
   - ★ Propagation: Seeds
   - ★ IIHR varieties: Kamini, Violet Cushion, Shashank, Arka Aadya, Arka Archana
   - ★ Aster yellow: Viral disease is transmitted by leaf hopper (*Macrosteles fascifrons*)

2. Alstroemeria

2. Inca/Peruvian Lily: 2n=2X=16 Origin: South America Family: Alstroemeriaceae
   - ★ Hardy perennial bulbous plants
   - ★ Protandry
   - ★ Required photoperiod for flower ind... 14hrs
   - ★ Propagation: Rhizom...

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3. Day lily

3. **Day lily:** *Hemerocallis*: Origin: Eastern Asia: 2n=2X=22 Family: Asphodelaceae
   - ★ Herbaceous perennial
   - ★ Toxic alkaloid: Hamercallin
   - ★ Yellow daylily: *Hemerocallis fulva*
   - ★ Golden or orange daylily: *H. auarantica*
   - ★ 1st colchicine induced tetraploid plant: *H. washingtonia*
   - ★ Synthetic species: *Hemerocallis s washingtonia*: Colchicine induced tetraploid
   - ★ Propagation: Division of clumps

4. Baby's Breath

4. **Gypsophila**: 2n=2X=34: Origin: Caucasus Mountains Family: Caryophyllaceae
   - ★ Cool season crop
   - ★ Major cut flower in Korea
   - ★ Suitable for rock garden
   - ★ *Gypsophila panniculata, Gypsophila arrostii*
   - ★ Used as filler material with other cut flowers

5. Stock

5. **Gilly flower**: *Matthiola incana* : Family: Brassicaceae
   - ★ Biennial crop
   - ★ Potential source of 3-linolenic acid which is used for dietary supplements and industrial uses
   - ★ Classified into 4 groups
   - ★ Most of cultivars developed from *M. incana* × *M. Sinuate*
   - ★ Resistant to bacterial blight (*Xanthomonas citri* pv. *incanae*) : *M. tricuspidata*
   - ★ Trisomic variety (2n=14+ 1): Snow Fake
   - ★ Trisomic carry "Ss" genes
   - ★ Trisomic: Production 100% double flowers suggested by Frost (1928)
   - ★ Propagation: Seeds
   - ★ Important cultivars: Cinderella Series

6. Lotus

6. **National flower of India**: *Nelumbo nucifera*: Origin: India Family: Nelumbonaceae
   - ★ Prefers tropical and subtropical climate

- ★ Most spectacular flower in the world
- ★ Associated with religion and culture
- ★ Sacred flower in India
- ★ Symbol of beauty and prosperity
- ★ Yellow lotus: *Nelumbo lutea*; Origin: North America
- ★ Yellow lotus introduced to India from USA
- ★ Variety: Krishna: Double rose colour
- ★ Lotus breeder: Perry D. Slocum, USA
- ★ Interspecific variety: Perry's Giant Sunburst [illegible]
- ★ Ideal temperature for flowering: 30-35°C
- ★ Commercial weed: Water Hyacinth
- ★ Common disorder: Leaf spot (*Cercospora spp.*)
- ★ Maximum depth of lotus seed sowing: [illegible]
- ★ Common method of propagation: Seeds
- ★ Seed having longer viability or impermeable seed coat
- ★ Tolerant to cold: *Nelumbo lutea*
- ★ Seedling to flowering: 1-2 years
- ★ Seed rate: 4-5kg/acre of pond or lake
- ★ Rhizome harvest during the month of October to November

7. Bougainvillea

7. **Glory of the garden:** *Bougainvillea* [illegible]
   - ✦ Propagation: Semi-hardwood cuttings
   - ✦ Eminent breeder of Bougainvillea in India: [illegible] Swarup

Varieties:

- ✦ IARI: Vishaka, Dr. B.P.Bal, Sonnet, Spring Festival, Summer Time, [illegible]
- ✦ IIHR: Chitravathi, Dr HB Singh, Jawahar Lal Nehru, Purple Wonder, [illegible]
- ✦ Natural mutant variety: Mary Palmer
- ✦ Multibracted varieties: Mahara, Cherry Blossom
- ✦ Variegated foliage variety: Thimma
- ✦ Bicoloured variety: Partha

8. Bird of paradise

8. **Bird of paradise:** *Strelitzia reginae*: Origin: South Africa Family: Strelitziaceae
   - ★ Herbaceous perennial, evergreen plant
   - ★ Cut flower species: *Strelitzia reginae*

9. Heliconia

9. **Parrot plantain/False plantain/Lobster's claws/Parrot flower:** Origin: Central and South America, Family: Heliconiaceae
   - ★ Ideal crop for coconut gardens
   - ★ 50% production in India: West Godavari District, Andhra Pradesh
   - ★ Ornamental part: Highly modified leaves and bracts
   - ★ Type pollination: Cross pollination
   - ★ Main pollinators: Humming birds and bats
   - ★ Propagation: Rhizome, side shoots and suckers
   - ★ Optimum temperature for cultivation: 21-35°C

10. Petunia

10. **Petunia**: *Petunia hybrida*: 2n=14 Family: Solanaceae
   - ★ Short life cycle: 4 months
   - ★ Tender perennial
   - ★ Type of pollination: Cross
   - ★ Mode of pollination; Honey bees
   - ★ Complex pollination syndrome exist
   - ★ Propagation: Seeds
   - ★ Model plant for genetic studies, genetic engineering (Flower colour)
   - ★ Type of male sterility: Genetic male sterility (GMS)

11. Amaryllis

11. **Belladonna lily:**
   - ★ Also known as Hippeastrum/Royal Dutch/Amaryllis/Trumpet Lily/Night Star Lily
   - ★ Amaryllis and Hippeastrum is a bulbous flowering plants
   - ★ Amaryllis means sparkle or twinkle
   - ★ Hippeastrum different from amaryllis: Solid scape and absence of scales between the filaments

- ★ 6 species mentioned in Firminger's manual of gardening in Hippeastrum in India
- ★ *Amaryllis belladonna* : Origin: South Africa
  - ✦ Deciduous plant, self sterility diploid
- ★ Hippeastrum: *Hippeastrum aulicum*: 2n=20: Origin: South America
  - ✦ Natural septaploid plant: *Hippeastrum blumeracia* (7X=77)
- ★ Breeding method: Line hybrid and group hybrid method

12. Gaillardia

12. **Blanket flower**: *Gaillardia pulchella*: Origin: North America Family: Asteraceae
   - ★ Tropical crop
   - ★ Frost hardy plant
   - ★ Grown in dry land, to reduce the soil erosion
   - ★ Used as loose flower and garland preparation
   - ★ Propagation: Seeds

13. Zinnia

13. **Poor man's rose**: *Zinnia elegans*: Family: Asteraceae
   - ★ Popular garden plant
   - ★ Nematicide flower crop e.g. *Meloidogyne arenaria*
   - ★ Cut flower species: *Zinnia aethiopica*
   - ★ Perennial species: *Zinnia linearis*
   - ★ Propagation: Seeds

14. Calla lily

14. **Arum lily**: *Zantedeschia aethiopica*: Family: Araceae
   - ★ Rhizomatous perennial herb
   - ★ Ornamental part: Corolla like spathe
   - ★ Propagation: Rhizomes

15. **Statice Sea lavender**:
   - ★ Limonium is a
   - ★ Commonly fo
   - ★ Cool season

- ★ Used for dry flower, cutflower and garden decoration
- ★ Cut flower species: *Limonium sinuatum*
- ★ Medicinal purposed: *Limonium propsum*
- ★ Propagation: Seeds
- ★ **Variety:** Midnight Blue

16. Lilium

16. Lilium: Family: Liliaceae

- ★ Monocot plant
- ★ Winter hardy species
- ★ Prefers sunny climate
- ★ Suceptible to high temperature (>30°C)
- ★ Plant growth regulator used for plant height control: Ancymidal, CCC, & Ethrel
- ★ **Important species belongs to Lilium group:**
  - ✦ Cut flower production: *L. longiflorum* (Easter lily, Trumpet lily)- Used for church decoration
  - ✦ Reflexed petal lily: *L. martagon* (Turk cap lilies)
  - ✦ Tiger lily: *L. tigrinum*: Origin: Japan, Triploid species: 2n=36
  - ✦ Double flowered lilum: *L. tigrinum* var. *flore-pleno* Edible species: *L. maximowiczii*
  - ✦ Oil yielding species: Madonna lily: *L. candidum*
- ★ **Blooming period:**
  - ✦ Asiatic lilies: Early June
  - ✦ Oriental lilies: July-September
  - ✦ Tiger lilies: September
- ★ **Resistant sources:**
  - ✦ *L. henryi*: Resistant to fusarium and virus
  - ✦ *L. candidum*: Tolerant to low temperature and low light , Year round flowering ability
  - ✦ *L. cauricum*: Resistant to Fusarium wilt
- ★ **Major problem:**
  - ▪ Gametophytic self-incompatibility
  - ▪ Interspecific incompatibility
- ★ Long day induce vegetative growth of the plant
- ★ IAA promotes bulblet formation
- ★ Propagation: Bulb/seeds

- ★ Bulbils producing lily: Tiger lily
- ★ Major disease: Leaf blight: *Botrytis eliptica*
- ★ Serious pest: Thrips (*T. vancckei*)
- ★ Serious pest on bulb: Mites
- ★ Physiological disorder: Leaf scorch or leaf burn or tip burn is due to high Mg and Al in soil
- ★ Bud blast is due to complex factors
- ★ Longer shelf life: 25% bud colour storage

ORNAMENTAL PLANTS

1. **Annual Flowers**
2. **Ornamental Shrubs**
3. **Ornamental Trees**
4. **Ornamental Palms**
5. **Ornamental Climbers**
6. **Lawn**
7. **Cactus and succulents**
8. **Bulbous plants**
9. **House plants/shade plants**

F. Annual Flowers

★ **Colour scheme and grouping of annuals:**

- ✦ Basic/Primary colours: Red, Yellow, Blue (RYB)
- ✦ Secondary colours: Orange, Green, Violet (OGV)
- ✦ Hard/Warm/Hot/bright colours: Red, Orange, Yellow (ROY)
- ✦ Soft/Cool/Light colours: Blue, Violet, Green (BVG)
- ✦ Neutral colours: White, Black, Grey (WBG)
- ✦ Monochromatic: Using of single colour
- ✦ Monochromatic: When hue with its light and dark colour are brought in arrangement
- ✦ Dichromatic: Using of two colour
- ✦ Polychromatic: Using of various colour
- ✦ Predominant colour in nature: Green
- ✦ Complementary/Contrasting colours: Blue + Orange, Red + Green, Violet + Yellow

Primary colours	Secondary colours
Blue + Yellow	Green
Yellow + Red	Orange
Red + Blue	Violet

- ✦ Analogous: Combination of blue and green, Yellow and orange
- ✦ Triads: Combination of Yellow, Blue and Red

★ **Based on flower colour:**

- ✦ White flowered annuals: Alyssum, *Callistephus chinensis*, Nigella
- ✦ Yellow and orange flowered annuals: *Calendula officinalis*, Zinnia, Tagetus
- ✦ Blue colour annuals: Ageratum, Corn flower, Linaria

★ **Based on growing season:**

- ✦ Winter season: Antirrhinum, China aster, Ageratum, Carnation, Pansy, Phlox, Nasturtium, Nigella, Salvia, cineraria, Gazania, Sweet alyssum
- ✦ Summer season: Cosmos, Coreopsis, Gaillardia, Portulaca, Sunflower, Tithonia, Zinnia
- ✦ Rainy season: Balsam, Cockscomb, Gomphrena, Marigold, Gaillardia

★ **Based on flowering season:**

- ✦ Early blooming annuals: Celosia, Balsam, Gomphrena, Salvia, Zinnia, Coreopsis, Salvia
- ✦ Late blooming annuals: Althea rosea, Antirrhinum, Carnation, Sweet William, Hollyhock

★ **Based on hardiness:**

- ✦ Hardy annuals: Sweet pea, Digitalis, Rudbeckia, Viola
- ✦ Tender annuals: Oxalis

★ **Fragrant annuals:** Phlox, Alyssum, Carnation, *Lathyrus odoratus*, Sweet William

★ **Specific practices:**

- ✦ "Pricking" term give to the operation of transferring the young seedlings to pan or tray
- ✦ Staking: Sweet pea, Morning glory, Nasturtium
- ✦ Pinching: Carnation, Marigold, Dianthus (Pink)

★ **Based on specific purpose:**

- ✦ Screening purpose: Hollyhock, Cineraria
- ✦ Peculiar shape: Clianthus
- ✦ Dry flowers: Statice, Helichrys… …y's lace, Nigella
- ✦ Cut flowers: Carnation, S… …Corn Flower
- ✦ Loose flowers: M… …Aster, Sunflower, Gaillardia
- ✦ Bedd… C…

- Shade loving: Ageratum, Alyssum, Calendula, Delphinium, Balsam, Verbena, Salvia, Phlox
- Annuals suitable for shady situation: Salvia, Cineraria
- Edging of beds and walks: Brachycome, Portulaca, Alyssum
- Hanging baskets: Ageratum, Petunia, Phlox, Zinnia
- Window boxes and hanging baskets: Candytuft, Nasturtium, Petunia, Phlox, Portulaca, Zinnia
- Potted plants: Carnation, Antirrhinum, Aster, Petunia, Cineraria, Pansy, Phlox, Petunia

★ **Rockery purpose:**

- Humid regions: Brachycome, Phlox, Ageratum
- Dried and cooler parts of India: Limonium, Linum, Schizanthus

★ **Propagation of annuals:**

- Bold seeded annuals: Sweet pea, Nasturtium, Sunflower, Morning glory
- Annuals which are difficult to transplant: California Poppy, Linaria
- Germination in dark: Nigella, Phlox, Amaranthus, Allium
- Germination in light: Nicotiana, Lobella, Echium

★ **Type of pollination:**

- Self pollination: Balsam, Clianthus, Lupin, Sweet pea
- Often cross pollination: Antirrhinum, Aster, Dahlia, Salvia, Linum, Linaria, Wall flower
- Cross pollination: Alyssum, Arctotis, Calendula, Cineraria, Gazania, Stock, Zinnia

★ **Mechanism for cross pollination in annual flowers:**

- Heterostyly: Primula
- Self incompatibility (SI): Ageratum, Antirrhinum, Daisy, Gerbera, Petunia, Nicotiana
- Cytoplasmic male sterility (CMS): Ageratum, Petunia, Sunflower

★ **Indian origin:** Gomphrena, Balsam, Lady's lace

★ **Sowing and transplanting time:**

Annuals	Sowing time	Transplanting time
Summer season annuals	Mid-February to Early March	March-April
Rainy season annuals	June	July
Winter season annuals	September	October

★ Ideal sowing time for annuals In South India: September to October
★ In Northern Hills, all annual flowers are grown during summer i.e March-April
★ In India, Pune and Bangalore all annuals can be grown due to it peculiar climate

Common name	Scientific name	Family	Other features
Blanket flower	*Gaillardia pulchella*	Asteraceae	
Dog flower	*Antirrhinum majus*	Asteraceae	Snap dragon/Bunny rabbit/Bunny mouth
Floss flower	*Ageratum houstonianum*	Asteraceae	Blue colour
Paper flower	*Acroclinium roseum*	Asteraceae	Pink and white, Paper daisy/Everlasting daisy
Monkey flower	*Mimulus tigrinus*	Scrophulariaceae	Striped like a tiger, Musky flower
Everlasting flower	*Helichrysum bracteatum*	Asteraceae	Yellow colour
Star flower	*Phlox drummondii*	Polemoniacae	
Sage flower	*Salvia splendens*	Lamiaceae	scarlet sage
Butterfly flower	*Schizanthus wisetonensis*	Solanaceae	Poor man's orchid
Wall flower	*Erysimum cheiri*	Brassicaceae	Yellow colour
Cone flower	*Rudbeckia bicolour*	Asteraceae	
Corn flower	*Centaurea cyanus*	Asteraceae	Blue colour/Blue bottle/Ragged sailor
Hyacinth flower	*Iberis spp.*	Brassicaceae	Candy tuft
Sun flower	*Helianthus annuus*	Asteraceae	Sultans autumn beauty
Mexican sunflower	*Tithonia diversifolia*	Asteraceae	
Pot marigold	*Calendula officinalis*	Asteraceae	Yellow colour
Cape marigold	*Dimorphotheca aurantiaca*	Asteracea	an daisy
Fig marigold	*Mesembryanthemum criniflorum*		one daisy/Ice plant
Annual chrysanthemum	*Glebio*		mum/Cr

Cock's comb	*Celosia cristata*	Amaranthaceae	
Love lies bleeding	*Amaranthus caudatus*	Amaranthaceae	
Bachelor's button	*Gomphrena globosa*	Amaranthaceae	
Zinnia	*Zinnia elagans*	Asteraceae	Riverside beauty, Firecracker, Princess
Sun Plant	*Portulaca grandiflora*	Portulacaceae	
Summer cypress	*Kochia scoparia var. tricophylla*	Chenopodiaceae	Summer foliage annual, Suit for sunny areas Fire Bush, Burning Bush
Lady's lace	*Pimpinella monoica*	Apiaceae	
Larkspurs	*Delphinium hybridum*	Ranunculaceae	
Phlox	*Linum grandiflorum*	Linaceae	
Trod flax	*Linaria bipartita*	Scrophulariaceae	
Hollyhock	*Alcea rosea*	Malvaceae	Pusa Sweta, P. Gulabhi, P. Krishna & P. Lalima
Coreopsis	*Coreopsis tinctoria*	Asteraceae	Pusa Tara
Cosmos	*Cosmos bipinnatus*	Asteraceae	Short day annual, Mexican aster
Cineraria	*Senecio cruentus*	Asteraceae	Shade loving plant
Clarkia	*Clarkia elegans*	Onagraceae	
Bells of Ireland	*Moluccella laevis*	Lamiaceae	Summer flowering annual
China Aster	*Callistephus chinensis*	Asteraceae	
Baby's breath	*Gypsophila elegans*	Asteraceae	
Lupin	*Lupinus hartwegii*	Fabaceae	
Nasturtium	*Tropaeolum majus*	Tropaeolaceae	
Love in the mist	*Nigella damascena*	Ranunculaceae	
Pansy	*Viola x wittrockiana*	Violaceae	King of annual flowers
Petunia	*Petunia hybrida*	Solanaceae	
Sea lavender/Statice	*Limonium sinuatum*	Plumbaginaceae	
Stock	*Matthiola incana*	Brassicaceae	

Sweet Alyssum	*Lobularia maritima*	Brassicaceae	
Sweet William	*Dianthus barbatus*	Caryophyllaceae	
Sweet Pea	*Lathyrus odoratus*	Fabaceae	
Shirley poppy	*Papaver rhoeas*	Papaveraceae	
California poppy	*Eschscholzia californica*	Papaveraceae	
Verbena	*Verbena hybrida*	Verbenaceae	
Swan river daisy	*Brachyscome iberidifolia*	Asteraceae	

G. Ornamental Shrubs

★ An area of the garden devoted exclusively to shrubs is called as "shrubbery border"

★ **Flowering shrubs:**
- ✦ *Hibiscus rosa-sinensis, Hibiscus mutabilis, Calliandra sp., Ixora parviflora, Nerium, Bougainvillea*

★ **Foliage shrubs:**
- ✦ *Acalypha tricolor, Codiaeum variegatum, Aralia, Eranthemum elegans, Graptophyllum, Pisonia alba*

★ **Flower and foliage shrubs:**
- ✦ *Hamelia patens, Bougainvillea, Buddleja davidii*

★ **Fragrant shrubs:**
- ✦ *Cestrum nocturnum, Cestrum diurnum, Murraya paniculata , Jasminum sambac, J. auriculatum*

★ **Specimen shrubs:**
- ✦ *Hibiscus rosa-sinensis, Hamelia patens, Thevetia peruviana, Murraya paniculata*

★ **Salt tolerant shrubs:**
- ✦ *Bougainvillea sp., Russelia ... ruviana, Nerium indicum, ... pulcherrima*

★ **Salt sensitive shrubs:**
- ✦ *Buddleja ...*

★ **Winter flowe...**
- ✦

★ **Propagation:**

- ✦ Seed: *Thevetia peruviana, Caesalpinia pulcherrima, Calliandra sp.*
- ✦ Cuttings: *Cestrum diurnum, C. nocturnum, Hamelia patens, J. sambac*
- ✦ Layering: *Ixora sp., Bougainvillea*
- ✦ Ground layering: *J. sambac, J. multiflorum*
- ✦ Terminal cuttings: *Eunymous japonica, Ficus panda, Brunsfelsia americana*

★ Most popular in Indian gardens as flowers are used for offering worship to Lord Shiva: *Thevetia peruviana*

★ Flowers are shed like tears by falling of morning sunrays: *Nyctanthes arbor-tristis* (Har-Shingar)

★ Shrubs highly suitable for ornamental hedge: *Lantana camera, Murraya panniculata*

COMMON SHRUBS

Common Name	Scientific name	Family	Flower colour
Yesterday, today, tomorrow	*Brunfelsia pauciflora*	Solanaceae	Blue
Lady of the night	*Brunfelsia americana*	Solanaceae	Yellow
Night Queen/*Raat ki Rani*	*Cestrum nocturnum*	Solanaceae	Creamish white
Day King/*Dinka Raja*	*Cestrum diurnum*	Solanaceae	White
Tree of sadness/Night jasmine	*Nyctanthes arbor-tristis*	Oleaceae	White
Snow bush	*Phyllanthus nivosus*	Phyllanthaceae	Foliage
Star cluster	*Pentas lanceolata*	Rubiaceae	Pink, Red, Crimson
Cape jasmine	*Gardenia jasminoides*	Rubiaceae	White
Mussaenda	*Mussaenda luteola*	Rubiaceae	Yellow
Poinsettia	*Euphorbia pulcherrima*	Euphorbiaceae	White
Peacock flower (Gulmohri)	*Caesalpinia pulcherrima*	Fabaceae	Red, Yellow
China shoe flower	*Hibiscus rosa-sinensis*	Malvaceae	Scarlet
Pigeon berry	*Duranta plumeri*	Verbenaceae	Blue
Cup and saucer	*Holmskioldia sanguinea*	Lamiaceae	Red
Hamelia	*Hamelia patens*	Rubiaceae	Red
Lolypop plant	*Pachystachys lutea*	Acanthaceae	Golden yellow
December flower/Barleria	*Barleria cristata*	Acanthaceae	Violet-Blue
Dancing lady	*Fuchsia hybrida*	Onagraceae	Red, Purple

Weeping merry/Fountain bush	*Russelia equisetiformis*	Plantaginaceae	Red
Kamini	*Murraya paniculata*	Rutaceae	White, Yellowish
Ixora	*Ixora parviflora*	Rubiaceae	White
Malti/Chandni	*Tabernaemontana divaricata*	Apocynaceae	White
Butterfly bush/Summer lilac Buddleia	*Buddleja davidii*	Scrophulariaceae	White
Pili Kaner	*Cascabela thevetia*	Apocynaceae	Red
Lal Kaner	*Nerium indicum*	Apocynaceae	White, Pink, Red
Shravani	*Lagerstroemia indica*	Lythraceae	White, Pink, Red
Chitra	*Plumbago auriculata*	Plumbaginaceae	Light Blue

Indian origin shrubs:

✦ Rukamini, Har-Shringar, Cup and saucer, Clerodendron, Crossandra, Chine [illegible] merry, Chandni

Topiary or Tree sculpture

★ The term 'topiary' is derived from Roman words *ars topiaria* meaning ornamental gardening

★ Topiary art started in the 1st Century A.D.

★ Topiary is a technique of shearing plants into non typical shapes, usually [illegible]

★ Topiaries are garden novelties (like espaliers)

★ Shaped into forms as fantastic imaginations like corkscrews, chess pieces, obelisks, cones, tables, and countless animals. e.g. Garden of Levens Hall in England

★ In India, the hanging gardens or Kamala Nehru Park of Mumbai is famous for topiary work

★ Most common shrubs for topiary: *Clerodendrum inerme* and *Duranta plumieri*

★ Temperate regions: Box (*Buxus sempervirens*) and English Yew (*Taxus baccata*)

★ Generally the typical shapes of birds and animals are done with *Clerodendrum* and *Leucaena*

★ Common shrubs used for shapes of domes, cones, spheres and umbrellas are [illegible] *Bougainvillea, Thuja occidentalis, Cupressus macrocarpa, Putranjiva roxburghii* [illegible] *Polyalthia longifolia*

H. Ornamental Trees

- ★ Planting of trees in avenues was done by Asoka (Father of road side avenue planting)
- ★ Arboriculture: Growing of trees for the purpose of science, education, recreation and landscaping
- ★ Silviculture: Growing of trees for forestry purpose
- ★ Arboretum: Grouping of different trees are planted and maintained for scientific study
- ★ Trees is established in large waste lands known as "woodland planting"
- ★ Espaliers: trees and shrubs that are allowed to develop only two dimensionally: they have height and width, but hardly any depth
- ★ Espaliers are most commonly grown against walls or fences
- ★ Each 30m width of trees can absorb about 6 to 8 decibels of sound under city
- ★ Neem and Tamarind trees are highly prized for their ability to filter the noise, dust and light
- ★ In India remarkable period between for the flush of blooms of many of the trees is February to June
- ★ To reduction of noise high speed traffic of national highways: 20-30m wide belts of trees
- ★ To reduction of noise moderate speed in the cities: 7 to 15m wide belts of trees
- ★ Reduction of air pollution: Poplar, Morus, *Ficus infectoria*
- ★ Suitable for reduction of noise: Evergreen trees
- ★ Water loving trees: *Bassia latifolia, Terminalia spp. Syzygium cuminii*
- ★ Fast growing trees and establishing quickly: Copper shield tree, *Melia azadirach*, Gulmohar and Neem
- ★ Slow growing trees: *Pterocarpus santalinus* and Tamarind

Common Name	Scientific Name	Family	Flower colour
Queen of Flowering Trees	*Amherstia nobilis*	Fabaceae	Vermillion
Flame of the Forest or Palas	*Butea monosperma*	Fabaceae	Scarlet orange
Tree of life	*Guaiacum officinale*	Zygophyllacea e	Blue
Tree of heaven	*Ailanthus excelsa*	Simaroubaceae	Foliage tree
Tree jasmine or Indian cork tree	*Millingtonia hortensis*	Bignoniaceae	White
Indian coral tree/parrot flower	*Erythrina indica*	Fabaceae	Scarlet red
Fountain or Indian tulip tree	*Spathodea campanulata*	Bignoniaceae	Orange scarlet

Pride of India	*Lagerstroemia speciosa*	Lythraceae	Mauve
Indian Laburnum or Golden Shower	*Cassia fistula* (Amaltas)	Fabaceae	Bright yellow
Pink shower tree	*Cassia grandis*	Fabaceae	Rose pink
Indian Mahagoni	*Toona ciliata*	Meliaceae	White
Copper shield tree	*Peltophorum pterocarpum*	Fabaceae	Pale yellow
Badminton ball tree	*Parkia biglandulosa*	Fabaceae	White
Shenbagam or Swarna Champak	*Magnolia champaca*	Magnoliaceae	Light yellow whitish
Blue gulmohar	*Jacaranda mimosifolia*	Bignoniaceae	Blue
Gulmohar or May flower	*Delonix regia*	Fabaceae	Orange scarlet
Trumpet flowers	*Bignonia magapotamica*	Bignoniaceae	Light pink
Bottle brush tree	*Melaleuca citrina*	Myrtaceae	crimson scarlet
Pagoda or Temple tree	*Plumeria spp.*	Apocynaceae	White or pink, (Fragrant)
Devils tree	*Alstonia scholaris*	Apocynaceae	White
Flowering gum	*Corymbia ficifolia*	Myrtaceae	White to pink
Asoka tree	*Polyalthia longifolia*	Annonaceae	Foliage tree
Sita Asoka	*Saraca asoca*	Fabaceae	Scarlet tree
Champa tree	*Magnolia grandiflora*	Magnoliaceae	Creamy white
Siris	*Albizia lebbeck*	Fabaceae	Foliage tree
Monky puzzle	*Araucaria heterophylla*	Araucariaceae	Foliage tree
Beef wood tree	*Casuarina equisetifolia*	Casuarinaceae	Dioecious foliage
Golden rain tree	*Koelreuteria paniculata*	Sapindaceae	Foliage
Sausage tree or balam khira	*Kigelia africana*	Bignoniaceae	Foliage (Coppery
Indian or False Almond or Badam	*Terminalia catapp*		
Fern leafed tree	*Filicium decipi*		
Travellor's palm	*Ravenala madagasca*		

- ★ Water loving trees: *Bassia latifolia, Terminalia spp. Syzygium cuminii*
- ★ Trees for checking air pollution: *Ficus infectoria, Poplar hybrida, Plumeria alba, Morus spp.*
- ★ Specimen tree (high cost: Araucaria spp. *Ficus elastica* var. *decora*)
- ★ Monkey tail fruits: *Heterophragma adenophyllum*
- ★ Trumpet shaped blue colour: *Jacaranda mimosifolia*
- ★ Trumpet shaped crimson colour: *Kigelia pinnata*
- ★ Drooping branches is specific pattern in *Salix babylonica*
- ★ Fan arrangements of leaves is specific pattern of "Travellers palm (*Ravenala madagascariensis*)"
- ★ Tiered branching pattern is specific to *Terminalia catappa*
- ★ Bearing fruits in the trunk pattern is specific to *Crescentia cujete*

I. Ornamental Climbers

- ★ Generally climbers are most suitable for roof gardens
- ★ Vines contribute an architectural quality to this building
- ★ **Climbers with different modified organs**
  - ✦ **Tendrils:** *Antigonon leptopus, Bignonia gracilis, Pyrostegia venusta, Clematis paniculata*
  - ✦ **Hook like thorns:** *Bougainvillea sp., Climbing roses*
  - ✦ **Roots and rootlets:** *Campsis grandiflora, Ficus repens*
  - ✦ **Secreting sticky substances from growing points:** *Ficus repens*
  - ✦ **Twiners:** *Echitis, Hiptage, Lonicera*
  - ✦ **Ramblers and stragglers:** *Quisqualis indica*
  - ✦ **Creepers:** *Morning Glory*
- ★ Vines climb in three ways depending on the species
  - ♣ Climbing by twining themselves around a trellis, fence, or another plant.
  - ♣ Vines produce fine tendrils that wrap around the supporting structure and allow the vine to climb
  - ♣ Vines produce holdfasts that permit the plant almost to glue itself to the support
- ★ Heavy climbers: *Quisqualis indica, Bougainvillea, Pyrostegia venusta, Clerodendrum splendens , Wisteria sinensis, Bignonia magnifolia, Beaumontia grandiflora*
- ★ Light climbers: *Lonicera japonica, Trachelospermum jasminoides, Clitoria ternatea*
- ★ Queen of climber: *Clematis paniculata*
- ★ Annual climbers: *Ipomea lobata, Clitoria ternatea*

- ★ Indian origin climbers: Indian Ivy, Sky flower, Nepal trumpet flower, Purple Coral, Butterfly pea creeper
- ★ **Main planting season:**
  - ✦ Evergreen climbers: July-September and February-March
  - ✦ Deciduous climbers is February-Early March
- ★ **Specific purpose:**
  - ✦ Screening: *Vernonia elaeagnifolia, Pyrostegia venusta*
  - ✦ Hedge: *Clerodendrum inerme, Bougainvillea*
  - ✦ Pot culture: *Bougainvillea, Clitoria ternatea*
  - ✦ Fragrant flowers: *J. grandiflorum, J. officinale, Trachelospermum jasminoides, Hiptage benghalensis, Clematis paniculata*
  - ✦ Partial shade: *Clerodendrum splendens, Petrea volubilis, Lantana camara, Trachalospermum jasminoides*
  - ✦ Shade loving climbers/suitable for indoor decoration: *Pothos, Monstera, Philodendron, Asparagus*
  - ✦ Climbers suitable for sunny situation: *Pyrostegia venusta, Quisqualis indica, Antigonon leptopus, Bougainvillea*

IMPORTANT CLIMBERS

Common Name	Scientific name	Family	
Duck flower	*Aristolochia grandiflora*	Aristolochiaceae	Bear claw shaped flowers
Virgin flower	*Clematis paniculata*	Ranunculaceae	
Grape flower vine	*Wisteria sinensis*	Fabaceae	Purple colour
Sky flower	*Thunbergia grandiflora*	Acanthaceae	Blue colour
Watch flower	*Passiflora laurifolia*	Passifloraceae	
Coral vine/Lovers chain	*Antigonon leptopus*	Polygonaceae	
Rangoon creeper	*Combretum indicum*	Combretaceae	Floriferous
Railway creeper	*Ipomoea palmata*		
Butterfly pea creeper	*Clitoria t*		
Nepal trumpet creeper	*Bea*		
Blue potato creeper	*S*		
Creeping tuberose			
Trumpet climber			

Indian ivy	*Ficus repens*	Moraceae	Foliage creeper
Purple wreath	*Petrea volubilis*	Verbenacae	Star shaped blue colour
Golden shower	*Pyrostegia venusta*	Bignoniaceae	Orange colour (Tubular shape)
Morning glory	*Ipomea learii*	Convolvulaceae	
Star jasmine	*Trachelospermum jasminoides*	Oleaceae	
Kanthali Champa	*Artabotrys odoratissimus*	Annonaceae	
Vernonia	*Vernonia elaeagnifolia*	Asteraceae	Evergreen foliage
Japanese honey suckle	*Lonicera japonica*	Caprifoliaceae	
Quamoclit	*Mina lobata*	Convolvulaceae	

J. Ornamental Palms

Uses of palms in the landscape garden:

- ★ Suitable for decoration of conservatories, verandahs, stair cases and for indoor decorations as potted palms
- ★ Suitable for single specimens in lawn: *Areca triandra*
- ★ Excellent specimen for avenue planting in the gardens: *Roystonea regia*
- ★ **Palms based on the trunk and its manifestation:** 4 groups

Groups	Examples
1. Solitary palms	*Cocos, Phoneix, Elaeis*
2. Clumping palms	*Areca lutescens, Rhapis*
3. Branching palms	*Hyphane indica* (Branching above ground) *Nipa fruticans* (Branching below ground)
4. Trunkless palms	*Phoenix acaulis*

Important palms:

Common name	Botanical name
Sago palm	*Cycas revoluta*
Royal palm	*Roystonea regia*

Fish tail palm	*Caryota urens*
Chinese palm	*Livistona rotundifolia*
Butterfly palm	*Dypsis leptocheilos*
Good luck palm/ parlour palm	*Chamaedorea elegans*
Pygmy date palm	*Phoenix roebelenii*
Bottle palm	*Hyophorbe lagenicaulis*
Indian doum palm	*Hyphaene indica*

K. Lawn

Heart of the garden/Lawn/Natural green carpet for a landscape

- ★ Concept of lawn was given by England
- ★ Most suitable grass for most parts of India: Hariyali or dhoob grass
- ★ Highly suitable grass for large areas and playgrounds: Bermuda grass
- ★ Highly suitable grass for smaller areas and home lawns: Korean grass
- ★ Shade tolerant grass or more suitable for shady region: Kentucy blue grass and St. Augustine
- ★ Most common cheapest but slowest method of lawn making: Dibbling of roots
- ★ Most expensive or Quickest method of lawn making: Turfing
- ★ Turf plastering is not suitable for dry areas
- ★ Major cultural operation: Rolling, Mowing, Sweeping, Scrapping and Raking
- ★ Rolling is to help anchorage of the grass
- ★ Mowing for preventing the excessive growth of grass
- ★ Sweeping is the removal of cut over grass
- ★ Scrapping is to avoid toughness
- ★ Break the cruse and removal of matting grass for providing aeration: Raking
- ★ Bricking is to replace the unhealthy patches in lawn
- ★ Astroturf: Synthetic lawn popularly used in developing countries in roof garden and cric stadium
- ★ Area of garden should be devoid to lawn: 60-75%
- ★ Depth of medium for lawn making should be
- ★ Grasses should not be allowed to gro
- ★ Seed rate for lawn making:
- ★ Seeds take about 3-5

★ Most widely used pre-emergence herbicide for lawn: Glyphosate
★ Major problematic weed in lawn: Chek motha (*Cyperus rotundus*)
★ Pale or Yellow lawn is due to N_2 deficiency
★ Fairy ring disease of lawn is caused by soil borne fungi like *Marasmius ordeades*, *Psalliota campestris* and *Leipiota morgani*

Major grasses used in lawn

Common Name	Scientific name	Features
Hariyali or Doob or Bermuda grass	*Cynodon dactylon*	Drought resistant
Korean grass or Japan grass	*Zoysia japonica*	Prefers open sunny situation
Manilla grass	*Zoysia matrella*	
Korean velvet grass	*Zoysia tenuifolia*	
Buffalo grass	*Stenotaphrum secundatum*	Suitable for shady region
Kikuyu grass	*Pennisetum clandestinum*	Suitable for acid soil and higher elevations
Blue grass	*Poa annua*	
St. Augustine/Charleston grass	*Stenotaphrum secundatum*	Highly shade and heat tolerant grass

L. Cactus and Succulents

Cactus (Pl. Cacti): Origin: South America

★ Cactus belong to the family: Cactaceae
★ Areoles or spine cushions are invariably present in all members of cactus
★ Characters of cacti:

1) All cacti are perennial in nature
2) Cacti have usually globular and columnar structure
3) Botanically cacti fruit: One seeded berry
4) All the cactus belong to Dicotyledonous group
5) Cactus flower petals arise from the top of the ovary

★ Cacti usually bloom once in a year

★ Ideal season for grafting in cactus: Spring or Autumn
★ Best time for grafting of cacti: September
★ The cacti of *Echnioceranae* subtribe are commonly known as 'Hedgehogs'
★ For better quality cacti house can locate in North-South direction
★ Melon cactus or Turk's cap is belongs the 'Cactanae' subtribe eg. *Opuntia* and *Disocactus*
★ Rapid method for multiplication of cacti rootstock: Cuttings
★ Commonly occurring epiphytic cactus is known as "Chain cactus"
★ Epiphytic firm cacti: *Epiphyllums*
★ Cacti grown in shade become lanky and do not flower
★ Cactus group are almost leafless except *Pereskia aculeatea* (Lemon vine)
★ All cacti are succulents but all succulents need not to be cacti

Important cactus	Scientific Name
Rattail cactus	*Disocactus flagelliformis*
Old man cactus	*Cephalocereus sensilis*
Monstrose apple cactus	*Cereus peruvianus monstrosus*
Golden barrel cactus	*Echinocactus grusonii* (Golden barrel)
Rainbow cactus	*Echinocereus dasyacanthus*
Queen of the night/ Blooming Nishagandhi	*Ephiphyllum oxypetalum* (Previously *Phyllocactus*)
Bird's nest	*Mammilaria camptotricha* (Nipple or Elephant tooth cactus)
Crab cactus	*Zygocactus truncata* (Thanks giving cactus) Monotypic genus
Toms Thumb	*Parodia aureispina*
Bunny Ears	*Opuntia microdasys*
Sea Coral	*Opuntia clavarioides*
Peruvian Old man	*Espo*
Chin cactus	
Powder puff cactus	
Night blooming c	
Moon light ca	
African m	

Succulents- Store moisture in their foliage or in stem or in rootstock

- Most of the succulents originated from Mexico (Hot and semi-arid regions of Asia and America)
- Pedilanthus often used as a "hedge border"
- Preferred habit: Dry or desert areas
- Succulents: fleshy foliage or stem or both
- Succulents suitable for window box gardening, bowl gardening, rockeries and hanging baskets
- Suitable succulents species for pots and rock garden: Agave and Furcraea
- Hedge purpose: Agave
- Edge purpose and carpet bedding: Echeveria

Important succulents

Common name	Scientific Name	Family
Century Plants or Agave	*Agave americana*	Amaryllidaceae
Sea Onion or Climbing onion	*Bowiea volubilis*	Liliaceae
Kalanchoe	*Bryophyllum*	Crassulaceae
Slipper Plant or Bird Cactus or Jew Bush or Red Bird Cactus	*Euphorbia tithymaloides*	Euphorbiaceae
Elephant bush	*Portulacaria afra*	Portulacaceae
House leek	*Sempervivum spp.*	Crassulaceae
Chain Plant	*Tradescantia navicularis*	Commelinaceae.
Snake Plant/ mother-in-law's tongue	*Sansevieria trifasciata*	Liliaceae
Christ thorn	*Euphorbia milii*	Euphorbiaceae
Spanish dagger	*Yucca gloriosa*	Asparagaceae
Flowering stone/Old man's tooth	*Lithops sp.*	Aizoaceae

M. Bulbous Plants

- Horticulturally, plants of tubers, corms, bulbs and rhizome groups are called "bulbous plants"
- Leading bulbous plant growing area in World: South Africa
- Leading bulbous plant growing area in India: Kalimpong (Sikkim)
- Bulbous plant having maximum area under cultivation: Gladiolus

- Hardy bulbs: Tuberose, Amaryllis, Canna, Crinum, Zephyranthes
- Tender bulbs: Gladiolus, Narcissus, Daffodils, Freesia, Dahlia
- Bulbs suitable for warm climate: Tuberose, Crinum, Zephyranthes
- Bulbs suitable for cool climate: Gladiolus, Narcissus, Daffodils, Freesia
- Bulbs need staking: Gladiolus, Dahlia, Lilies
- Annual tricolour chrysanthemum (*C. carinatum*)
- **Propagation:**
  - Tuber: Dahlia
  - Corms: Gladiolus, Freesia
  - Bulbs: Amaryllis, Tuberose, Zephyranthes, Crinum
  - Rhizome: Canna, Iris, Calla lily
- **Specific purpose:**
  - Cut flower: Gladiolus, Tuberose, Amaryllis, Calla lily
  - Pot plants: Dahlia, Amaryllis
  - Mass effect: Dahlia, Canna, Zephyranthes
  - Essential oil: Tuberose
  - Goose neck harvest: Narcissus, Daffodil
- Most suitable soil for production of bulbs: Sandy loam or loamy sand
- Ideal pot mixture for bulb plants should be 2:2:2:1: ½ (Sand: Leaf mould: FYM : Soil : Charcoal)
- Generally bulbs are planted at 7-10cm depth
- Generally bulbs are planted at 30 × 20cm spacing
- **Separation of bulbs:**
  - Hardy bulbs: 2-3 years
  - Tender bulbs: 70-85 days
- Lily of the valley: *Convallaria majalis* (Asparagaceae)
- Lilly of the Nile: *Zantedeschia* (Araceae)

Common Name	Scien	Family	Origin
Night star lily/Trumpet lily	*Hi*		
Cape Lily/St. John Lily/Sudarshan/Sukhdarshan			South Africa
Belladonna Lily/King or st Lily/Star of India			
Spider lily			

Orange day lily/tiger day lily	*Hemerocallis fulva*	Liliaceae	
Zyphyr lily	*Zephyranthes rosea*	Amaryllidaceae	South America
Glory lily/State flower of Tamil Nadu	*Gloriosa superba*	Colchicaceae	India (Tropical Asia)
Red cape lily/Blood flower	*Scadoxus multiflorus*	Amaryllidaceae	
Calla lily/Arum Lily	*Zantedeschia spp.*	Araceae	South America
Cobra/Snake lilies	*Arisaema spp.*	Araceae	
Indian shot/American beauty/Status of liberty	*Canna indica*	Cannaceae	Tropical America
Gerbera/Transvaal or African/Barberton daisy	*Gerbera jamesonii*	Asteraceae	South Africa
Flag flower	*Iris spp.*	Iridaceae	Southern Europe
Magic flower	*Achimenes longiflora*	Gesneriaceae	
Wind flower	*Anemone spp.*	Ranunculaceae	
Narcissus/Daffodils/Nargis	*Narcissus spp.*	Amaryllidaceae	Asia
Rajani Gandha/Tuberose	*Polianthes tuberosa*	Asparagaceae	Mexico
Shell ginger/Hedychium	*Alpinia speciosa*	Zingiberaceae	Sikkim and Bhutan

N. House Plants/Shade Plants

- **Ideal temperature for indoor plants:** 15-21°C
- **Relative humidity:** 40-60%
- **Light:** 15-25 foot candles (16hr light/day)
- **Suitable for window garden:** Aglaonema, Aracaria, Sanseveria, Diffenbachia, Poinsettia, Zebrina, Begonia, Aspidistra
- **Suitable for :** *Aspidistra, Selaginella, Scindapsus, Maranta, Monstera*
- **Easy to manage house plants:** *Ficus, Dracena, Chlorophytum, Scindapsus, Mara*
- **Climbing/trellis:** *Hedera, Ficus pumila, Cissus, Philodendron*
- **For bowl/terrarium/bottle:** *Begonia, Billbergia nutans, Fittonia, Calathea*
- Growing condition: Green house, lath house or varandha of buildings

Common Name	Scientific name	Family
Ribbon plant	*Chlorophytum comosum*	Asparagaceae
Spider plant	*Chlorophytum comosum vittatum*	Asparagaceae
Shrimp plant	*Justicia brandegeeana*	Acanthaceae
Artillery plant/Pistol plant	*Pilea macrophylla*	Urticaceae
Aluminium plant	*Pilea cadierei*	Urticaceae
Money plant/Pothos/Devil's Ivy	*Epipremnum aureum*	Araceae
Algerian Ivy	*Hedera canariensis*	Araliaceae
Ghost tree	*Hedera canariensis variegata*	Araliaceae
Wondering Jew	*Tradescantia zebrina*	Commelinaceae
Butcher's broom	*Ruscus aculeatus*	Asparagaceae
Song of India	*Dracaena reflexa*	Asparagaceae
Moses in the cradle	*Tradescantia spathacea*	Commelinaceae
Pepper face	*Peperomia sp.*	Piperaceae
Red Dracaena	*Cordyline fruticosa*	Asparagaceae
Bryophyllum	*Kalanchoe sp.*	Crassulaceae
Purple heart/ Purple Heart, Purple Queen	*Tradescantia pallida*	Commelinaceae
Bat flower	*Tacca sp*	Dioscoreaceae
Carimen	*M*	Araceae
Crotons		Euphorbiaceae

Alocasia	*Alocasia sp.*	Araceae
Foxtail fern/ Plume asparagus	*Asparagus densiflorus*	Asparagaceae
Cast-iron Plant	*Aspidistra elatior*	Asparagaceae
Heart of Jasus/ Angel Wings	*Caladium hortulanum*	Araceae
Peacock Plant/Brain Plant	*Calathea sp.*	Marantaceae
Fittonia/Nerve plant	*Fittonia spp.*	Acanthaceae
Caricature Plant/Jamaican Croton	*Graptophyllum pictum*	Acanthaceae
Spiderwort	*Tradescantia spp*	Commelinaceae

CPK

O. PROPAGATION OF ORNAMENTAL PLANTS

I. Sexual propagation	
A. Seed germination	
Annuas lost viability within	6-12 months
Lotus seed germinated after	150-200 days
Little moisture for germination	Portulaca, Eschscholtzia
Light required for germination	Veronica, Ranunculus, Gynerneae
Light inhibit the germination	Nigella
Light Slightly inhibit the germination	Larkspur

II. Asexual propagation	
A. 1. Cuttings	
Softwood cuttings	Carnation, Chrysanthemum, Coleus, Delphinium, Jasmine, *Hibiscus*
Soft hardwood cuttings	Jasmine, Hydrangea
Hardwood cuttings	*Ficus bengalensis, Glyricidia maculata, Erythrina indica*
Semi hardwood cuttings	Abelia
Herbaceous cuttings	Geranium, Chrysanthemum, Coleus, Carnation
Leaf cuttings	Sansivieria
Leaf bud cuttings	Camellia, Rhododendron, Blackberry
Leaf vein cuttings	Red Begonia
Semi-hard wood stem cuttings	*Duranta, Hibiscus,* Crotons

2. Stem cuttings (3 types)	
Terminal cuttings (Tip portion of shoot)	Carnati
Heel cuttings (Lateral shoot)	
Node cuttings	

3. Root cuttings	
Herbaceous group	Gypsophila, Gaillardia, Achillea, Anemone
Woody group	Aralia, Clerodendrum, Lagerstroemia

4. Leaf cuttings	
Leaf stalk	Peperomia, Saintpaulia
Entire leaf	Rex Begonia
Leaf strips	Begonia rex, Peperomia
Shrub	Peperomia, Saintpalia, Gerbera, Kalanchoe, Rex begonia, Bryophyllum, *Sedum spectabilis, Viburnum rhytidophyllum*
Leaf bud cuttings	Poinsettia, Hydrangea, Geranium, Camellias

5. Layering	
Simple layering	Jasmine, Oleander
Mound or stool layering	Cestrum, Deutzias
Compound or serpentine layering	*Jasminum sambac*
Continuous or Trench layering	Hydrangea, Dianthus
Division	*Russelia juncea*, Tuberose, Chrysanthemum
Separation	
Bulb	Hyacinth, Crowns
Suckers	Shrubs: Ixora, Jasminum
	Trees: *Millingtonia hortensis, Holarrhena antidysenterica*

6. Grafting	
Inarch grafting	Rose (West Bengal, Bihar), *Allamanda violacea, Petrea volubilis*
Side grafting	Camellias
Saddle grafting	Rhododendron, Lilac
Flat grafting	Scions for cactus, Cereus, Cephalocereus
Cleft grafting	Prolonged in finger cactus

7. Specialised plant parts	
Rhizome	Canna
Stolon	Chlorophytum
Tubers	Begnonia, Dahlia
Bulbs	
i. Tunicate bulbs	Daffodil, Tulip
ii. Non-tunicate bulbs	Lily
Slabs	Narcissus
Corms	Gladiolus
Bulbils	Narcissus

ROLE OF PGR IN FLORICULTURE:

- ★ Auxin synergist: TIBA, Coumarin
- ★ Anti-auxin: Trans-cinnamic acid
- ★ Epinastic: Aceylene, ethylene and carbon monoxide (CO)

IBA for cuttings:

- ★ Orthodox method: 25-100 ppm @ 24 hrs
- ★ Quick dip method: 1000-10,000 ppm @ 5 seconds or 2 minutes
- ★ Regeneration of seed and bulb formation: GA3, Cytokinin, Morphactins
- ★ Bulb formation: Cytokinin: Lilies
- ★ Cormel formation: Gladiolus @ 20 ppm

Plant height control:

- ★ SADH: Chrysanthemum
- ★ Cycocel, Alar: Chrysanthemum
- ★ Phosphone: Lily
- ★ Cycocel: Poinsettias
- ★ B-Nine: Dahlia
- ★ CCC: Malvaceous crops
- ★ MH: Bougainvillea

Regeneration of flower

- ★ Early blooming
- ★ Early flower

★ GA_3 induces flowering in long day plants

Special pruning techniques in Flower crops

Special Techniques	Purpose	Examples
Root pruning: Removal of roots 40 cm away from the plant	To make dwarf, to induce flowering , fruitfullness and determining the flowering time	Rose
Disbudding: Removal of unwanted flower buds in cluster of flowers	To induce the showy good quality flowers	Carnation, Chrysanthemum, Dahlia
Pinching: Removal of terminal growing point in herbaceous plants	To induce the lateral or side shoot production	Carnation, Chrysanthemum

Special cultural operations in flowers:

★ Wintering is considered as alternative to root pruning

★ Wintering is done for rose and jasmine in Northern and Eastern India

★ In Jasmine, common practice is to defoliate plants after pruning just prior to flowering season

★ Chemical defoliants-Pentachlorophenol has been used as defoliant in Jasmine

★ Defoliation is common practice in *Jasmine* and *Nasturtium*

★ **Deshooting**

- Removal of unwanted shoots
- Common practises in carnation for cut flower trade and chrysanthemum for exhibition purpose
- Part of disbudding

★ **Disbudding**

- Refers to removal of the superfluous flower buds only at an early stage of growth
- Done at a stage of when the plants are young and between 7 to 15 cm in height
- General practice of disbudding is to retain only one bud per shoot and to obtain quality blooms
- Common practice in Carnation, Chrysanthemum, Marigold, Dahlia and Zinnia

★ Stopping or pinching refers to the removal of the growing point of shoot along with a few leaves

★ Pricking means transferring of young seedlings (4 to 6 leaf stage) to another pan or tray

★ Adventitious roots very common in philodendron, originate on the lower stem.

P. Diseases of Flower Crops

Diseases	Causal organism	Remarks
	A. Loose Flowers	
1. Jasmine		
Leaf spot	*Cercospora jasminicola, Alternaria jasmini*	Major problem in Pitchi (*J. grandiflorum*)
Rust	*Uromyces hobsoni*	
2. Crossandra		
Foot and root rot	*Phytophthora nicotianae*	
Flower blight	*Aleternaria sp.*	
3. Tuberose		
Basal rot	*Sclerotium rolfsii*	
Flower blight	*Botrytis elliptica*	
4. Marigold		
Wilt and stem rot	*Phytophthora cryptogea*	
Leaf spot and blight	*Alternaria sp.*	
5. Chrysanthemum		
Wilt	*Fusarium oxysporum f sp. chrysanthemi*	
Stem rot	*Fusarium solani*	
Root rot	*Pythium sp and Phytophthora sp*	
Bacterial blight	*Erwinia chrysanthemi*	
Leaf spot and flower blight	*Septoria chrysanthemella*	
Chrysanthemum stunt	*Viroids*	
6. China aster		
Collar and root rot	*Phytophthora cryptogea*	
Wilt	*Fusarium spp.*	
	B	
1. Rose		
Powdery mildew		
Downy mildew		
Black spot		
Die-back		

Rust	*Phragmidium spp.*	Serious disease in warm and humid tropics
2. Carnation		
Wilt	*Fusarium oxysporum f sp. dianthi*	Resistant variety: Novada
Foot rot	*Phytophthora sp., Pythium sp, Rhizoctonia solani*	-
Basal rot	*Sclerotium rolfsii*	-
Leaf spot	*Alternaria dianthi*	-
Bacterial wilt	*Pseudomonas caryophylii*	Resistant spp.: *D. capitatus, D. neuteri*
3. Gladiolus		
Wilt/Soft rot	*Fusarium oxysporium f sp. gladioli*	Also known as: Core rot, vascular disease
Neck rot	*Botrytis gladidorum,*	Soft corm rot/grey mould/Floral rot
Leaf and flower blight	*Curvularia trifoli, C. eragrostidis*	-
Aster yellows	MLO's	Vector: Leaf hopper
4. Anthurium		
Bacterial wilt	*Ralstonia solanacearum*	Major problem
Bacterial blight	*Xanthomonas campestris* cv. *diffenbachiae*	-
Anthracnose	*Colletotrichum gloeosporioides*	Major problem in high rainfall areas
Black rot and leaf blight	*Phytophthora nicotianae* var. *parasitica and P. citrophthora*	-
5. Orchids		
Flower blight	*Botrytis cinerea*	-
Heart rot	*Phytopthora palmivora*	-
Pythium rot	*Pythium ultimum*	
Leaf spot	*Cercospora* and *Phyllostictina*	
6. Gerbera		
Foot rot	*Phytophthora cryptogea*	
Wilt	*Fusarium oxysporium* f. sp. *dianthi*	
Blight/Grey mould	*Botrytis cinerea*	
Powdery mildew	*Oidium crysiphoides f. sp. gerbera*	

Q. Physiological Disorders of Flower Crops

Crops	Disorders	Symptoms	Causes	Control measures
1. Rose	Bull rose	Flattened or distorted flowers	Genetic control, low temperature, high vigour stems	Optimum temperature: Day: 21°C and Night: 17°C
	Blind shoots	Abortion of flower buds	Low light intensity	Maintain high CO_2 and light intensity
	Charming black		Drought stress supplemental lighting	
2. Carnation	Calyx splitting	Proliferation of petals, abnormal calyx expansion	Low N, Boron, High ammonical N_2, Temperature variations	Maintain night temperature: Above10°C, Rubber banding before flower opening
	Sleepiness	Upward curling, cupping or bending of petals	Ca deficiency, Sensitive to ethylene, High temperature during storage	Storage at free from ethylene producing products
	Curly tip	-	Boron deficiency	-
	Grassiness	No flower production	Genetic factors of variety	-
3. Chrysanthemum	Crooked neck	Bending of neck Common: winter months	Day night temperature variations	-
	Bronze colour foliage	Pb deficiency	-	-
	Bleached petals	-	High temperature during f development	-
	Quillings of flower petals	-		-

	Crown buds	-	temperature 3°c Insufficient light intensity
	Bract buds	-	Day night temperature exceeds 27.2°C
4. Lily	Bud drop	-	Insufficient light conditions
	Leaf scorch	-	Ca deficiency
	Blindness	-	Unfavourable climate
	Topple or bud rot	-	Ca deficiency
	Puffy foliage	Stunted plants	Frost injury
	Bud blast	-	Low light intensity, high nitrate level
5. Gladiolus	Fluoride injury	Burn symptoms	Occur tip of the leaves
6. Orchids	Dry sepal injury	-	High humidity and smog
	Deformed flowers or browning of throat	-	Low temperature and chilling injury
7. Alstromeria	Flower abortion or blast	-	Excessive salt or over watering

- Sensitive var: Snow Princess
- -
- -

Post harvest problem in flowers:

- Water uptake is major problem in Anthurium
- Gerbera: Drooping, Stem break
- Negative geotropism: Gladiolus (uneven distribution of auxins)
- Shattering
- Loss of leaves, buds, petals, flowers, or even branchlets, a process called 'shattering', or 'abscission', is also a common problem in cut flowers
- Leaf yellowing and senescence: Yellowing of leaves and even of other organs (buds, stems) commonly is associated with the end of display life in some cut flowers e.g. alstroemeria and lilies
- Flower senescence: early déath of flowers is a common cause of quality loss and reduced vase life for cut flowers e.g. Tulip, Iris, and Narcissus

Chapter – 6 : Plantation Crops

1. TEA
2. COFFEE
3. COCONUT
4. RUBBER
5. ARECANUT
6. COCOA
7. CASHEWNUT
8. PALMYRAH
9. OIL PALM

A. PLANTATION CROPS

1. Tea

1. **Golden leaf/Queen of Beverage Crop/Tea:** *Camellia sinensis*: Theaceae: 2n=30: Origin: China
   - ☆ Tey is a Chinense language
   - ☆ Evergreen beverage shrub (China jats) or tree (Assam jats)
   - ☆ Calcifuge crop [Plant which cannot tolerate alkaline/calcareous soil]
   - ☆ Southeast Asia is the original home for tea
   - ☆ Best soil pH for cultivation of Tea: 3.2-6.2
   - ☆ Most of the tea plants under cultivation are diploid (2n = 30)
   - ☆ Commercially cultivated as a rainfed crop
   - ☆ Tea 1st introduced by Mr. Robert Kyd (1780) (colonel R.kyd – 1780)
   - ☆ Study of tea is known as Tsiology
   - ☆ India is the largest producer, consumer and exporter in tea industry
   - ☆ India is the world's largest producer of organic tea
   - ☆ India is the largest producer of black tea
   - ☆ Unique "brothy" taste due to L-Theanine
   - ☆ Responsible for briskness, brightness and colour of the liquor: Aflavins and arubigins
   - ☆ Responsible for colour of black tea: Theaflavins and Thearubigens
   - ☆ Major polyphenols present in
   - ☆ Major phenolics in gre
   - ☆ Health properties in t

Brotty – We

[Astringent – Sour/bitter]

- ☆ Stimulative effect of tea is due to caffeine (1.25-4.5%)
- ☆ Tea astringent taste is due to tannins (Polyphenols)
- ☆ Fresh tea leaves contain approximately 36% polyphenolic compounds (catechins, quercetin, myricetin)
- ☆ **Three main types of tea produced from leaves:**
  - Green tea (non-fermented)
  - Oolong tea (partly fermented)
  - Black tea (fermented)
- ☆ **Black tea**
  - Commonly consumed in India, the United States and Western countries
  - More widely consumed than green tea worldwide
  - Rich sources of the flavonol aglycons (quercetin)

Important species:

- Assam jats: *C. assamica*- Sparse flowering
- China jats: *C. sinensis*- Profuse flowering, hardy and resistant to frost and drought
- Indo-china or cambod type: *C. assamica* ssp. *lasiocalyx*- Natural hybrid

☆ Flowers: Bisexual and Fruit: Capsule

☆ Soil amendment for maintaining soil pH: Agricultural lime ($CaCO_3$), dolomite lime ($CaMg(CO_3)_2$)

☆ Commercial propagation: Single node cuttings

☆ In South India, Silver oak (*Grevillea robusta*) is used as a permanent shade tree

☆ **Temporary shade trees:**

- *Indigofera teysmannii* (Most commonly utilized), *Glyricidia sepium*

☆ **Centering**

- Training method
- Removal of main stem at a height of about 20 cm from the ground:
- Promotes the axillary bud or lateral branches

☆ Skiffing is the lightest form of pruning and collar pruning is the s… rejuvenation of tea garden

☆ Bush frame is done by decentering, light pruning, debudding …

☆ Height of permanent bush frame 35-45cm from ground le…

☆ Formative pruning is done at 5 years after planting (40-5…

☆ Tipping is the practice of removal of terminal portion of …

☆ Tipping: 1st plucking of recovering bushes

☆ Cataphylls or Janams: First 1-2 scale leaves covered by axillary bud

☆ Fish leaf: Above scale leaves- photo synthetically active normal leaf

☆ Banjii shoot means dormant shoots

☆ Single banji: one leaf and a bud, double banji: two leaf and a bud

☆ Half of the 1st opened leaf or apical bud known as 'Banjii bud'

☆ Mother leaf: Series of 3 or 4 normal leaves

☆ Mother leaf plucking is done at January to March

☆ Light plucking: Plucking of shoots upto mother leaf

☆ Hard plucking: Plucking of shoots below a mother leaf

☆ Best plucking or harvesting in tea is two leaves and a bud

☆ Janm plucking is the most common practice in North Eastern states

☆ Most labour intensive operation tea industry: Plucking

☆ Phyllocron or leaf expansion time:

☆ Number of days taken from unfolding of successive leaves (one Leaf + bud in 7 days)

Tea research

☆ UPASI started in 1945

☆ United Planters Association of South India (UPASI), Coop, Tamil Nadu

☆ UPASI Tea research station, Valparai, Tamil Nadu

☆ UPASI is an apex body of tea, coffee, pepper and cardamom in the South… Tamil Nadu, Karnataka and Kerala

☆ Tocklai Tea Experiment Station was established in 1911, Jorhat, Assam

Varieties:

☆ Mites is a serious problem: Major mite: Pink mite (*Acaphylla theae*)

☆ Blister blight of tea is caused by *Exobasidium vexans*- Translucent spot on tender leaves and stem

☆ Yellowing of tea is due to sulphur deficiency

2. Coffee

2. King of beverage crop/Coffee: *Coffea spp.*: Rubiaceae: 2n=22: Origin: Ethiopia

☆ Coffee is one of the world's most valuable export commodities, ranking second in the world market after petroleum products

☆ Coffee introduction: 16th Century 'Muslim pilgrim': Baba Budan, Chikmagaluru, Karnataka

☆ 2nd important commodity in the world trade after petroleum products

☆ Central Coffee Research Institute (CCRI) is located at Balahanur, Chikmagaluru, Karnataka

Important species:

- ✦ Arabica coffee: *Coffea arabica*- 2n=4X=44, Self-pollinated, self-fertile, allotetraploid, high elevation, shrub, Origin: Ethiopia
- ✦ Robusta coffee: *C. caenephora*- 2n=2X=22, Cross pollinated, self-sterile, lower elevation, tree, Origin: Central Africa
- ✦ Tree coffee: *Coffea liberica*
- ✦ *C. liberica* has been used as source of resistance to leaf rust

☆ Short day plant

☆ *C. arabica* best cup quality (low caffeine content and fine aroma) most important species occupies a 70% of the world production.

☆ Fruit type: Drupe (2 seeds)

☆ Flowering time: September to March

☆ Summer showers is important for flowering

☆ Ideal temperature for cultivation:

- ✦ Arabica: 25-25°C
- ✦ Robusta: 20-30°C

☆ Fruit development from flowering time: Arabica: 8-9 months and Robusta: 10-11 months

☆ Planting time (16 to 18 months old): June or September-October

☆ Pruning system: Centering, Desuckering, Handling and Nipping

☆ Training system in coffee is single stem system: Most common method in India

☆ Multiple stem system: Most commonly practised in Kenya and Tanzania

☆ Scuffling/soil stirring (for control weeds and soil moisture conservation) is done towards the beginning of the dry period

☆ **Temporary shade tree:**

- ✦ Dadap (*Erythrina indica*)-Most commonly used in India and Silver oak (*Grevillea robusta*)

☆ **Permanent shade tree:**

- ✦ *Albizzia lebbeck, Cedrella tonna, Dalbergia latifolia, Ficus glomerata, Maesopsis eminii*

☆ Permanent shade for coffee is (*Grevillea robusta*) and temporary shade is *Indigofera teysmanni*

☆ Topping is a cultural practice in wet coffee processing

Varieties	Remarks
Kents	Earliest variety of Arabica
San Roman	Mutant variety
Sln.795	Resistant to leaf race 1, 11 and most popular variety arabica coffee
Sln. 8	Spontaneous hybrid of robusta-arabica origin, high vertical resistance to leaf rust
Sln.9 and Sln. 10	Drought hardy, suitable for different coffee zones
Cauvery (Caturra × Hybrido-de-Timor)	Resistant to all races of coffee rust variety

☆ Cauvery (Catimor) is popular variety in India

☆ Sln.9 - This variety has won the Fine Cup Award for best Arabica at the 'Flavour of Indi

☆ Fly picking: Selective picking of ripe berries

☆ Main picking: After fly picking- 4-6 pickings @ 10-15 days interval

☆ Stripping: Picking of remaining green berries (Final harvest)

☆ Clean felling is not advocated in coffee

☆ Founder of coffee research in India: Dr. L.C. Coleman

Processing of coffee:

☆ **Preparation of parchment coffee:**

- Pulping
- Dry... ...ging (by Natural ... ...ith alkali,

☆ Plantati...

☆ Che...

☆ I...

☆ Natural fermentation time: 24-36 hrs for arabica and 72 hrs for robusta

☆ Time for alkali treatment (10% Caustic soda, NaOH): 1hr for arabica and 1 ½-2 hrs for robusta

☆ Coffee blending: Cichorium used as additive: To improve colour, odour and taste is called as French coffee

Physiological disorders:

- Bean disorders common in Arabica coffee: Black bean, black jollo and normal jollo
- Abortion of one ovule: Pea berry
- False polyembryony or triangular seeds: Presence of 3 or more seeds
- Elephant Bean: Formation of more than one ovule per locule
- Die-back is the physiological disorder in coffee
- Premature fruit drop is due to wet feet condition, CHO and hormonal imbalance, and nutrient deficiency

Pest and diseases:

★ Coffee leaf rust (*Hamelia vestatrix*) introduced from Sri Lanka

★ White stem borer (*Xylotrechus quadripes*): Wilting and yellowing of leaves

★ Coffee berry borer (*Hypothenemus hampei*): Most serious pest in the world

★ Coffee berry borer is controlled by *Beauveria bassiana* (Fungal bio-control agent)

★ Shot hole borer (*Xylosandrus compactus*): Extensive tunnelling

★ Coffee nematodes (*Pratylenchus coffeae*): Dieback

3. Coconut

3. **King of Species/Tree of Heaven /Kalpavriksha/Tree of life:** *Cocos nucifera:* Araceae: 2n=32:

Origin: South East Asia

☆ Humid tropical perennial monoecious palm

☆ Monotypic genus

☆ Heliophile plant

☆ Coconut is a crop of small and marginal farmers

☆ Among the plantation crops, coconut is the major crop grown both under plantation and homestead management system

☆ India's largest agricultural imports is Edible oils

☆ Imports of edible oils constitute almost half of total domestic consumption of edible oils about 70 % from palm oil

☆ Oils and fats important constituents of human diet and crops constitute the main source of oil (80%)

☆ Wold leading coconut oil producer: Philippines (43%)

☆ World production of vegetable oils is dominated by four crops viz., oil palm (35%), soybean (28%), ,rape seed/canola and sunflower

☆ Total production of coconuts in India:

- 50 % used as mature nuts
- 35 % Copra
- 15 % Tender form for drinking purposes

☆ Coconut oil contains lauric acid

☆ Suitable for homestead system of farming , mixed cropping and intercropping

☆ 70-75% of the plantation area can be utilized for cropping systems

☆ Mixed stand as a backyard crop

☆ Total production of coconuts in the country, about 50% is used as mature nuts, 35% is used for copra and 15% is consumed in the tender form for drinking purposes

☆ Sunlight requirement for profuse growth and productivity: 2000 hrs/years

☆ India is the 3rd largest producer after Indonesia, Philippines

☆ Tamil Nadu is the leading coconut producer in the country

☆ India accounts 22.34% of the world coconut production

☆ Tender coconut water calorific value: 17.4 KCal

☆ Highest productivity: Lakshadweep: 19630 nuts/ha

☆ Highest production: Kerala

☆ World Coconut Day: 2nd September

☆ Type of fruit: One seeded drupe

☆ Type of inflorescence: Spadix

☆ Genetically the dwarf palms are autogamous while tall types are allogamous

☆ Main pollinating agents: Wind and insects

☆ In India, female flower production is high during the month of March-May, low in September-January

☆ Generally number of female inflorescence: 10-50

☆ Number of spadix produce per annum: 12-15

☆ Receptivity of female flowers: 19-20 days after opening of spathe

☆ Coconut is propagated by only through seedlings

☆ Time period of spadix initiation to ripening of nuts: 42 months

☆ Time period for germination of nuts: 11-12 weeks

☆ Recommended planting system [illegible] coconut [illegible] Square system (7.5 x 7.5 m), 175 palm[illegible]

☆ Pure coconut [illegible]

- ☆ Surface planting is adopted in Maharashtra and Coastal Karnataka
- ☆ Coconut seednut is planting at vertical position
- ☆ Square system suitable for tall varieties
- ☆ Hedge system is suitable for seed gardens and dwarf varieties
- ☆ Hedge row system: 5.0-5.55m × 9-10m (Suitable for perennial and annual crop in interspaces)
- ☆ Percentage of female flowers reach maturity under normal condition is 25-40%
- ☆ Active root zone of coconut utilize 25% of available land
- ☆ Water requirement of per palm: 200cm (conventional irrigation) and 30litres/day/palm (drip irrigation)
- ☆ Suitable intercrops:
  - ✦ Fruits: Pineapple, Banana
  - ✦ Vegetables: chilli, elephant foot yam, sweet potato, tapioca
  - ✦ Most profitable intercrop: Banana
- ☆ Multitier cropping is followed in coconut gardens
- ☆ Leguminous cover crops for green manure: *Pueraria phaseoloides, Mimosa invisa and Calopogonium* species, *Stylosanthes gracilis* (For mixed farming)
- ☆ Suitable green manure crop: Glyricidia
- ☆ Suitable mixed crops for coconut plantation:
  - ✦ Cocoa, pepper, cinnamon, clove and nutmeg
- ☆ For enhancement of fruit set: NAA @ 200 ppm
- ☆ High nut (35%) obtained during the summer months: March-May
- ☆ Harvesting interval time: 45 days (summer months) and 60 days (rainy season)
- ☆ Yield: Tall variety: 60-80 nuts/palm/year
- ☆ Hybrids yield: 100-140 nuts/palm/year
- ☆ Average coconut yield: 44 nuts/palm/year
- ☆ Generally all dwarf cultivars grown for tender nut purpose
- ☆ Pratap (Pure line Selection), Banawali (Selection from Banawali)
- ☆ Polyembryony variety: Arasikere Tall

Varieties:

Dwarf types (For tender coconut)	**Tall types** (Largely grown in India)
Pre-bearing age: 3-4 years	Pre-bearing age: 6-10 years
Chawghat Orange Dwarf (COD)	East Coast Tall (ECT)
Chawghat Green Dwarf (CGD)	West Coast Tall (WCT)

Malayan Orange Dwarf (MOD)	Laccadive Ordinary(LCO) of Cherukara
Malayan Green Dwarf (MGD)	VPM-3: Selection from Andaman Islands
Malayan Yellow Dwarf (MYD)	
Gangabondam	

Hybrids:

Hybrids	Parents
Kalpa Sankara	CGD × WCT
Kalpa Samrudhi	MYD × WCT
Kalpa Sreshta	MYD x TPT
Kera Sankara	WCT × COD
Chandra Shankara	COD x WCT
Chandra Laksha	LCT × COD
Laksha Ganga	LO × GB
VHC-1	ECT × MGD
VHC-2	ECT × MYD
VHC-3	ECT × OD
Kera Sankara	WCT × COD
Kera Ganga	WCT × GB
Kera Sree	WCT × MYD
Kera Sowbhagya	WCT × SSAT
Anantha Ganga	ECT × GB
Godavari Ganga	ECT × GBGD
Konkan Bhatye	GBGD × ECT

CPCRI varieties:

- **Tall cultivars:** Kalpa Mitra, Kalpa Pratibha, Kalpa Thenu, Kalpa Tharu, Kalpa Haritha, Chandra Kalpa
- **Dwarf cultivars:** Kalpa Raksha, Chowghat Orange Dwarf (COD), Kalpa Sree (oil purpose), Kalpa Jyothi (yellow), Kalpa Surya (orange)
- Kalpatharu: Suitable for ball copra production
- Kalpa Sankara: Hybrid suitable for root (wilt) disease
- Kalparaksha and Kalpasree dwa
- Kalpa Haritha: Tolerant to eri

- ☆ Tender coconut dwarf varieties: Chowghat Orange Dwarf, Kalpa Jyothi, Kalpa Surya
- ☆ Commercially manufacturing copra: Milling copra
- ☆ Coconut Research Station (CRS), TNAU, Veppankulam, Pattukottai
- ☆ Milling copra is most popular in Southern India (Kerala: 60-65%)
- ☆ Cup copra is most popular in Northern India
- ☆ Coir is obtained from mesocarp
- ☆ Tapping of coconut is done for toddy
- ☆ National Agricultural Cooperative Marketing Federation of India Ltd (NAFED), established in 1958, procure the copra from market with a Minimum Support Price (MSP)
- ☆ International Coconut Genetics Network, Rome
- ☆ International Coconut Gene Bank (ICGB)- India, Indonesia, Papua New Guinea, Cot dIvoire
- ☆ World Coconut Germplasm (WCG) is located at Sipoghat, Andaman Nicobar Islands
- ☆ Coconut Development Board (CDB) is located at Cochin, Kerala
- ☆ CDB comes under Ministry of Agriculture established at Kochi in 1981, Kerala

Physiological disorders:

- ☆ Crown choking or Button shedding: boron deficiency
- ☆ Button shedding (Immature nut fall) is due to lack of pollination and fertilization, defects in the flowers, physiological disorders, genetic nature of the variety, pest and disease and unfavourable environment
- ☆ Rosette/Little leaf: zinc deficiency

Pest and diseases:

- ☆ Rhinocerous beetle and Red palm weevil: most destructing pest in coconut
- ☆ Rhinocerous beetle (*Orycetes rhinoceros*): Characteristic geometric cut (inverted 'V' shape)
- ☆ Bioagent- *Oryctes Baculovirus* against rhinoceros beetle
- ☆ Red palm weevil (*Rhynchophorus ferrugineus*): Oozing out of a viscous brown fluid and longitudinal splitting of leaf bases
- ☆ Rodents control: Placing of single dose anticoagulant bromodiolone (0.005%)
- ☆ Root feeding: Combination of Monocrotophos @10 ml and water @10 ml for control of red palm weevil
- ☆ Eriophyid mite (*Aceria guerreronis*) is serious pest in coconut
- ☆ Invasive species or emerging pest: Hispine beetle, *Brontispa longissima* and Scale insect, *Aspidiotus rigidus* major threat to coconut cultivation
- ☆ Stem bleeding (*Thielaviopsis paradoxa*)- Exudation of reddish brown liquid on trunk
- ☆ Thanjaur wilt (*Ganoderma lucidum*)- Bleeding patches on the stem- Root feeding
- ☆ Bud rot (*Phytophthora* palmivora): Yellowing of two young leaves and emitting foul odour

- ☆ Root wilt caused by Phytoplasma, Vector: Lace bug (*Stephanitis typica*) and Leaf hopper (*Proutista moesta*) Abnormal bending of ribbing of the leaflet are symptoms of leaflet-Prevalent throughout Kerala and Tamil Nadu
- ☆ Leaf rot caused by fungal pathogens: *Colletotrichum gloeosporioides*, *Curvularia rostratum* and *Fusarium solani*
- ☆ Fruit rot and Immature nut fall: *Lasiodiplodia theobromae*

4. Arecanut

4. **Betel nut/Supari**: *Areca catechu*: Araceae: 2n=32: Origin: Malayan Archipelago/Indonesia
- ☆ Monoecious palm
- ☆ Mixed stand as a backyard crop
- ☆ In India, Arecanut is popular for masticatory purpose and used either with betel leaves or scented supari
- ☆ Arecanut grown as a rain-fed crop in West Bengal, Assam and Southern parts of Kerala
- ☆ India is the largest producer and consumer of Arecanut
- ☆ Polyphenols and tannins responsible for astringent taste of nuts
- ☆ India ranks first in both area (49%) and production (50%) of Arecanut
- ☆ Karnataka leading area and production of Arecanut in india
- ☆ Inflorescence type: Spadix
- ☆ Fruit- Monolocular, Single seeded berry
- ☆ Type of pollination: Cross
- ☆ Pollinating agent: Honey bees
- ☆ Largest arecanut grown areas in laterite soil
  - ✦ *Areca triandra*: Ornamental value due to suckering habits and produces red colour
  - ✦ *Areca concinna*: Suckering palm and scarlet red fruit colour
- ☆ Recently reported sweet kernel arecanut species in Mysore: *Areca catechu* var. *deliciosa*
- ☆ Propagation: Seeds
- ☆ Spacing: 2.7 m × 2.7 m
- ☆ Planting system: Square system
- ☆ Suitable cover crops: *Mimosa invisa*, *Stylosanthus gracilis* and [illegible]oides
- ☆ Arecanut plantation: Cocoa, Black Pepper is suitable for multi

Varieties:

CPCRI, Regional station, Vittal, Kerala		
Varieties	**Breeding methods**	**Specific features**
Mangla	Introduction from China (VTL-3)	Semi-tall variety
Sumangla	Selection from Indonesia (VTL-11)	Tolerant to burrowing nematode (*Rad*)
Sreemangla	Selection from Singapore (VTL-17)	Tolerant to burrowing nematode
Sreevardhan	Indigenous to Maharashtra	Commercially grown in coastal Maharashtra
Swarnamangala	Mohit nagar × HD hybrid	High yielding dwarf variety
Mohitnagar	Indigenous to West Bengal	Popular in West Bengal
SAS-1	Sirsi Arecanut Selection-1	Suitable for tender nut and ripe nut processing
CAL-7	Calicut-7	Popular in Andaman and Nicobar Islands
VTLAH-1	Hirehali dwarf × Mohitnagar	Arecanut hybrid dwarf variety
Indigenous popular cultivars		
Thirthahalli and South Kanara		Malnad area Karnataka
Kahikuchi		Assam
SAS-1		Popular in hill regions of Karnataka
Shreewardhanee		Selection from Shriwardhan l

- ☆ Arecanut forms 5-6 leaves per year
- ☆ Full bloom to maturity of the arecanut fruit: 35-47 weeks
- ☆ Normal yield in any plantation: >10 kg of ripe nuts/palm @ 10th year
- ☆ Most popular arecanut trades: Chali or Kottapak type
- ☆ Nuli is made from tender nuts
- ☆ *Chali*/Kottapak: Prepared from dried ripened (9 months old) arecanut is popular in Northern India and Western India
- ☆ Kalipak is prepared from immature dark greennut (6-7 months), popular in Kerala and Karnataka
- ☆ Iylon- well known trade mainly consumed in Tamil Nadu and Andhra Pradesh

Pest and diseases:

- ☆ Major pest- Spindle bug(*Calvalhoia areacae*)
- ☆ Koleroga or Mahali disease is caused by *Phytophthora arecae*- Nut shedding, Water soaked lesions

- ☆ Inflorescence die back: *Colletotrichum* species
- ☆ Budrot or bud rot is caused by *Phytophthora meadii* - Spindle appearance
- ☆ Anab-e-Roga is caused by *Ganoderma lucidum*- Exudation of oozing
- ☆ Yellow leaf disease (YLD) is caused by MLO (Mycoplasma like organisms). Transmitted by vector plant hopper *Proutista moesta*

5. Cocoa

5. **Food of God**: *Theobroma cocoa*: Malvaceae: 2n=20: Origin: Amazon valley of South America

- ☆ Cocoa, a beverage crop having high commercial potential
- ☆ Mostly grown in India as a mixed crop in arecanut and coconut gardens
- ☆ Cocoa is considered as a functional food because rich source of polyphenols and antioxidant properties
- ☆ Shade loving, evergreen tree
- ☆ Humid tropical crop
- ☆ Beverage crop
- ☆ Rich source of fat (37%) and protein (7%)
- ☆ Largely grown as a homestead crop (mixed Crop) in Kerala in the coconut and arecanut gardens
- ☆ Leading Cocoa producing country in the world: Côte d'Ivoire
- ☆ Tamil Nadu has the highest area under cocoa (34%) while cocoa production, Kerala has the major share (42%).
- ☆ Type of fruit: Indehiscent drupe (Pods)
- ☆ Young fruits are called as cherelle
- ☆ Cocoa grows in a series of storeys branches
- ☆ Jorquetee is a plagiotropic branches
- ☆ Chupon: Axillary bud grown just below the jorquette and it grows vertically
- ☆ Inflorescence: Cauliflorous
- ☆ Type of pollination: Cross pollination is due to self incompatibility
- ☆ Mode of pollination: Insects
- ☆ Optimum temperature for cocoa cultivation: 2
- ☆ New method of propagation in cocoa: Mi
- ☆ Viability of cocoa seeds: 7 days
- ☆ Propagation: Softwood grafting
- ☆ Main crop spacing: 2.7 m × 2.7
- ☆ In arecanut garden: 5.4 m× 2

- ☆ Planting time: May-June
- ☆ Training system: Open centre or central leader type
- ☆ Centering (Cultural operation) is a process of removal of lateral branches
- ☆ Moisture content of well dried beans is 6-7%
- ☆ Two major varieties (Naturally evolved):
  - ✦ Criollo-Dark red pod colour
  - ✦ Forestero-Yellow pod colour
  - ✦ CPCRI: VTLCC-1 (Vittal Cocoa-1)
- ☆ Forastero is a recommended variety for commercial cultivation by CPCRI, Kerala
- ☆ Trinitaria from Trinidad: Hybrid between Criollo × Forestero: High variable pod characters
- ☆ Amelonado: Forestero type-Melon shaped pods, Cultivated in West Africa
- ☆ Best quality type of cocoa: Criollo types (Colour of cotyledon- Whitish or pale brown)

Stage	Forastero	Criollo
Pod colour		
i. Immature stage	green	red
ii. Mature stage	yellow	yellow or orange
Cotyledon Colour		
i. Fresh	Purple	White
ii. Fermented bean	Dark brown or chocolate brown	Cinnamon colour

- ☆ Cocoa pods takes to mature and ripe: 140-160 days
- ☆ Generally cocoa gives 2 main crops/year: September-January and April-June
- ☆ Moisture content for safe storage of cocoa beans: 6-7%
- ☆ Moisture content of fermented beans: 55%
- ☆ Coco butter is used for chocolates
- ☆ The International Cocoa Organization (ICCO) is located in London

Pest and diseases:

- ☆ Major disease: Black pod or stem canker disease (*Phytophthora palmivora*)- Pods turn chocolate brown to black
- ☆ Serious pest: Cocoa mealy bug (*Planococcus lilacinus*)
- ☆ Cherelle wilt or rot: Caused by *Colletotrichum gleosporioides*

6. Cashewnut

6. **Plough crop/Gold mine of waste land/Dollar earning crop/Wonder nut**: *Anacardium occidentale*: Anacardiaceae: 2n=42: Origin: Eastern Brazil

- ☆ Due to its nutritive value and commerce designated as "Zero cholesterol nut or white gold"
- ☆ Precious gift of nature to the mankind
- ☆ Evergreen tree, hardy tropical plant
- ☆ Sensitive to waterlogging
- ☆ Very hardy and drought resistant
- ☆ The cashew was introduced from Brazil to india (16th century) by Portuguese
- ☆ Introduced to India to cover bare hills and for soil conservation
- ☆ India is the first country which commercialized cashew as a horticultural crop
- ☆ Largest producer in the world: Vietnam
- ☆ India occupies largest area (20.30%) of the total area under cashew in the world
- ☆ India largest processor, exporter, importer and consumer of cashew
- ☆ Indian cashew kernel is graded best in quality in the International market
- ☆ Cashew kernels contain protein (21%), fat (47%), carbohydrates (22%), phosphorus (0.45%), calcium (0.05%), iron (5 mg/100 g)
- ☆ India is the 2nd largest producer in the world
- ☆ To cashew producing states: Maharashtra, Andhra Pradesh and Odisha
- ☆ Highest productivity in India: Maharashtra (1.5 t/ha)
- ☆ Cashew apple is a rich source of Vitamin-C (261.5 mg/100 g
- ☆ Predominant acid in cashew apple: Malic acid
- ☆ Cross pollinated crop and highly heterozygous
- ☆ Polycross breeding method commonly used for improvement (used especially those crops have small hermaphrodite flowers)
- ☆ Pollinators: Insects (Flies, bees) and wind
- ☆ Jumbo nut size >10 g
- ☆ Cashew apple is fleshy peduncle
- ☆ Type of Fruit: Drupaceous nut
- ☆ Type of Inflorescence type: Terminal panicle
- ☆ Polygamomonoecious: Flowers are either bisexual or stam… interminsed in the same inflorescence
- ☆ Flowering period: November an…
- ☆ Cashew Nut Shell Liquid (C… of shell
- ☆ CNSL is used in indus…

☆ Propagated by epicotyl (50-60% success rate) and soft wood grafting (40-70% success rate)
☆ Soft wood grafting is recently recommended for commercial adoption
☆ Softwood grafting (30-40 days old seedling) is similar to epicotyl grafting except age of the rootstock
☆ Problem in mound layering or stooling in Cashewnut: Absence of taproots in seedling
☆ Times taken for germination: 15-20 days
☆ Planting time: June-July
☆ Spacing: 7 m × 7 m or 8 m × 8 m
☆ Preferable branching type: Intensive branching
☆ Intensive branching for high yielding tree : >60% and for low yielding tree (<20%)
☆ Top working: Beheading (20-25 years old trees @ 0.5m height) is done during December-February
☆ Top working: Cleft grafting commonly used

Varieties:

Released from	Varieties
Bapatala, Andhra Pradesh	BPP-1,2,3,4,5,6
Vengurla, Maharashtra	Vengurla-1,2
Vridhachalam, CRS, TNAU	VRI-1,2,3,4
Ullal, Karnataka	Ullal-1,2,3,4, Chintamani-1
Kerala	Anakkayam-1, BLA-39-4, K-22-1, Madakkathara-1,2
NRCC, Puttur, Karnataka	Bhaskara, NRCC Selection-1, NRCC Selection-2
Hybrids	Kanaka, Priyanka, Amrutha, Dharasree, Akshaya, Vengurla-3,4,5,6,7, 8
Priyanka	Export variety
Jhargam-1	Commercially cultivated in West Bengal

✦ Directorate of Cashew Research (DCR) (former National Research Centre for Cashew) was established in 1986 at Puttur, Karnataka
✦ Cashewnut Research Station (CRS), TNAU, Vridhachalam, Tamil Nadu
☆ Peak time of harvest: March-April
☆ Yield: 6 kg/tree (15 years old trees)
☆ Deblossoming is done in 1st two years and only 3rd year onwards allow to flowering

Processing:
✦ Roasting => Shelling => Extraction of oil => Peeling => Grading => Packing (Recharge with CO_2)
✦ Oil bath roasting process (For uniform roasting of nuts): 200-202°C @ 3 minutes
☆ Grading is done based on counts (number of kernel/pound)
☆ Wholes (No split on the kernel) grade contain 6 grades
☆ Major pest: Tea mosquito bug (*Helopeltis antonii*)

7. Rubber

7. **Para rubber/Natural Rubber**: *Hevea brasiliensis*: Euphorbiaceae: 2n=36: Origin: Brazil
★ Deciduous tree
★ Rubber is introduced in Asia:1876
★ Commercial cultivation of rubber in India was started in 1902
★ Major rubber producing countries: Malaysia, Indonesia, Thailand and Africa
★ Most important commercial source of natural rubber: Para rubber
★ Alternative source for natural rubber: Guayule (*Parthenium argentatum*) as a source of high quality latex
★ Rubber is amphidiploid (2n = 4x = 36)
★ Breeding cycle in rubber extends to 20-30 years

Other rubber species:

Common name	Botanical name
Cera rubber	*Manihot glaziovii*
Indian rubber	*Ficus elastica*
Panama rubber	*Castiolla elastica*
Guayul rubber	*Parthenium argentat*

★ RRII-105: Highest yi id clone in th
★ Hevea seeds norma July-Septe
★ Polyclonal seed g of high y ed for natural open pollination
★ According to rubb s of cl India
★ Clonal seeds (Hig

Propagation metho
★ Commercial prop

- Brown budding →Buds taken from one year old shoot
- Green Budding → Buds taken from young shoot
- Crown Budding →Replacing the undesirable crown of a high yielding clone with a desirable crown

★ Spacing: 4.9m×4.9m

★ Latex is obtained from the bark of the rubber tree by tapping

★ Tappable stage: 7th years onwards (75% of trees attains tappable girth)

Ideal for tapping:

- Seedling →55 cm girth and 50 cm height (From the ground)
- Budded trees → 50 cm girth and 125-150 cm height (From the bud union)

★ Tapping depth: 1mm close to cambium

★ Tapping slope: 25°-Seedlings tree and 30°-Budded plants

★ Slaughter tapping: Intensive tapping prior to felling of the old trees

★ Swellings: Callus formation at tapping place

★ Stimulation and increasing the latex yield: Ethrel or Ethephone + Coconut oil @10% a.i (Thrice a year)

Tapping density:

Intensity		Commonly followed tree	Remarks
S_2d_2	100%	Budded plant	Tapping alternated days for 6 months
S_2d_3	67%	Cloned seedlings	Tapping at every 3 days for 6 months
S_2d_1	200%	Followed by small growers	Daily tapping (Favours brown blast)

★ Tapping time: Early morning (Turgor pressure in the latex vessel is high and latex flow is fast)

★ Tapping is not done in rainy days

★ National average yield: 1.6 t/ha

★ Rubber tree deciduous leaves during the month of December to February

★ Total life span of rubber plantation: 20-22 years of tapping

★ Latex contains 32% dry rubber content

- Coagulants: Acetic or formic acid
- Anti-coagulants: Formalin, Ammonia, Sodium sulphite

★ Smoking house temperature: 40-60°C + high RH

★ Measuring of rubber percentage: Metrolac, Latex meter

★ Standard rubber consistency: 12-15%

Grades:

- Dry ribbed rubber: RMA series
- Dry crepe rubber: EPC series

★ International Rubber Research and Development Board (IRRDB), Kuala Lumpur, Malaysia

★ Association of Natural Rubber Producing Countries (ANRPC), Kuala Lumpur, Malaysia

★ Rubber Research Institute of India (RRII-1955) is located at Kottayam, Kerala

★ Tapping panel dryness (TPD) or brown blast is the major physiological disorder in rubber

★ Exact causes of TPD is unknown, Recommendation: Low frequency tapping

★ Most common and widely followed processing: Sheet rubber

★ Mostly used cover crops in South India:

- *Pueraria phaseoloides, Centrosema pubescens, Mimosa invisa, Calapogonium muconoides*

★ Abnormal Leaf fall: *Phytophthora botryosa* and *P. palmivora*

★ Powdery mildew of rubber: *Oidium haveae*

8. Palmyrah

8. **State Tree of Tamil Nadu /Kalpaka virucham/ Kalpaga thara/Tree of Life:** *Borassus flabellifer*: 2n=36: Origin: Tropical Africa Family: Arecaceae

☆ Tropical, dioecious palm

☆ Neera or padaneer contains sugar (12-16%),Vitamin-C and B-complex

☆ Toddy: Natural uncontrolled fermentation of sugary sap: Alcohol content-5%

☆ Palm sugar: Boiling of stained and clarified sap to 108-110°C @ 85°Brix

☆ Nungu: Tender Palmyrah fruit-Rich in CHO, P, Fe, Vitamin-C and Riboflavin

☆ Flowering season: January-August

☆ Peak flowering season: May

☆ Two variants: Black colour and Red colour

☆ **Variety: SVPR-1- Semi-dwarf variety**, Palmyrah Research Station, Srivilliputhur, TNAU

☆ **Tending:** Periodically removing the persisting leaf bases

☆ **Tapping**: Extraction of sap from the inflorescence

☆ **Method of extraction of tapping in male palm:**

- Aripanai (1-1½ months old inflorescence) and Vallupanai (1month old inflorescence)
- Thattupalai: Young female inflorescence

☆ **Method of extraction of tapping in female palm:**

- Kaivetty: 2-3 months old female inflorescence

☆ Normally female palm is tapped for a longer period (April-December) compared to male palms (Dec-Feb)

9. Oil palm

9. **Small Holders Irrigated Crop/Oil Palm/Crop for future:** *Elaeis guineensis*: Araceae: 2n=32: Origin: West Africa

★ Humid tropical palm
★ Oil palm was first introduced to India at National Royal Botanical Gardens, Kolkata, 1886
★ Oil palm: highest edible oil yielding perennial crop
★ Oil palm is a high yielding crop (more than 5 tonnes of oil per hectare per year) as compared to other oil yielding crops that are yielding around one tonne of oil per hectare
★ It produces two distinct oils, i.e., palm oil and palm kernel oil, which have commercially used for culinary and industrial purpose
★ Palm oil is derived from the fleshy mesocarp of the fruit, which contains about 45-55 per cent of oil
★ The palm kernel oil, obtained from the kernel of stony seed, is a potential source of lauric oil
★ Indian Institute of Oil Palm Research (IIOPR), Pedavagi, Andhra Pradesh
★ Major oil palm growing country: Malaysia
★ Commercial propagation: Seed

Three variants/types:

i. Dura (Shell is present)
ii. Pisifera (shell absent)
iii. Tenera (Dura × Pisifera)- High mesocarp content

★ Type of pollination: Cross
★ Oil palm is an entomophilous crop
★ Mode of pollination: Weevil (*Elaeidobius kamerunicus*)
★ Pollinating weevil introduced from Malaysia
★ Leaf pruning is commercially followed in oilpalm
★ Ablation is a removal of male and female flowers in early stage of plantation
★ Stripping is a removal of berries from the bunches after harvest

Suitable Cover crops:

✦ *Pueraria phaseoloides, Calopogonium mucunoides, Centrosema pubescens, Mimosa invisa, Mucuna sp.*

★ Palm oil is extracted from the mesocarp of fruits
★ Palm oil is rich in palmitic acid
★ Palm Kernal Oil is extracted from the kernal of fruits
★ Crude palm oil (Rich in vitamin A and E): Extraction from fleshy orange red mesocarp.
★ Crude palm oil which on refining becomes palm oil commercially known as palmolein.

□□□□□

B. Diseases of Plantation Crops

Diseases	Causal organism	Remarks
1. Tea		
Blister blight	*Exobasidium vexans*	Major foliage disease
Black root disease	*Rosellinia arcuata*	Major problem in N-E India
Red root disease	*Poria hypolateritia*	
Brown root disease	*Fomes noxius*	
2. Coffee		
Leaf rust	*Hemileia vestatrix*	Major disease, Introduced from Sri Lanka
Black rot	*Koleroga noxia*	
Brown blight/twig blight dieback	*Colletotrichum kahawae*	Coffee berry disease (CBD)
3. Coconut		
Bud rot	*Phytophthora palmivora*	
Stem bleeding	*Thielaviopsis paradoxa*	
Thanjavur wilt	*Ganoderma lucidum*	
Kadang-Kadang	*Virus*	Vector: Stephanitis typicus
Root wilt	*Phytoplasma*	Vector: Stephanitis typicus
4. Arecanut		
Koleroga/Mahali	*Phytopthora arecae*	Major disease
Bud rot	*Phytopthora palmivora*	
Anabe-roga	*Ganoderma lucidum*	Wilt symptom
Yellow leaf disease	*Mycoplasma like organisms (MLOs)*	
5. Cocoa		
Black pod disease/Canker	*Phytophthora palmivora*	
6. Cashew		
Dieback/Pink disease	*Pellicularia salmonicolor*	
Anthracnose	*Colletotrichum gloeosporioides*	
7. Rubber		
Abnormal leaf fall	*Phytopthora sp.* (*P. meadii*-Most common)	Most [illegible] Indi[illegible]
Powdery mildew	*Oidium haveae*	

Chapter – 7 : Spices and Condiments

A. Spices-Introduction

- ★ The term 'Spice' was derived from the Latin "species aromatacea", means 'Fruits of the earth'
- ★ Most of the spices are native of India, Land of Spices
- ★ Spices not only add flavour and taste to our food but also enhance keeping quality and medicinal values of food
- ★ Spices are high value and low volume commodities of commerce in the world market.
- ★ India being the world leader in seed spice production, consumption and export
- ★ Home of spices/Spices bowel of India- Kerala
- ★ Out of 109 spices about 63 spices grown in India
- ★ Seed spice crops are extensively cultivated in the arid and semi-arid region of India
- ★ The spices listed by the International Organization for Standardization (ISO)
- ★ Out of the total 63 spices grown in India, 20 are classified as seed spices
- ★ The seed spices 36 per cent share in area and 17% share in production of total spice in India.
- ★ Kerala is the leading pepper producing state
- ★ India is the largest producer exporter of turmeric and ginger in the world
- ★ India is the largest producer of chilli in the world
- ★ Among the export of different spices, maximum share was from chilli (40%) followed by seed spices (25%)
- ★ Andhra Pradesh (AP) contributes 25% of area and 48% of production followed by Karnataka
- ★ Current organic spices export is about 2%
- ★ Temperate spices: Saffron and kalazeera
- ★ Saffron and kalazeera: Most expensive and popularly known as "Golden Spices"
- ☆ India's major export of spice products are in the raw and bulk form: 80%
- ☆ Spice oil is obtained by steam distillation
- ☆ The residual solvent in the oleoresin should be <30ppm
- ☆ Spices oils and Oleoresins account for > 80% of the export of earnings from value ... spices
- ☆ Indian spices have obtained geographical indicators such as Malabar pepper, A... Cardamom, Coorg Green Cardamom and Naga chilli

Classification of spices:

Classification of Spices based on growth habit:

- ★ Herbs: Coriander, cumin, fennel, fenugreek, chilli, parsley
- ★ Shrubs: Rosemary, perennial chilli, pomegranate
- ★ Trees: Garcinia, nutmeg, clove, cinnamon, tamarind,
- ★ Climbers: Black pepper, tailed pepper, vanilla
- ★ Perennial herbs/Rhizomatous herbs: Ginger, turmeric, mango ginger, asafoetida

Commerical classification based on production/importance:

- ★ Major spices: Black pepper, cardamom, ginger, turmeric, chilli
- ★ Major seed spices: Coriander, cumin, fennel, fenugreek
- ★ Minor seed spices: Ajowan, celery, parsley, dill, caraway, black cumin, black caraway
- ★ Major tree spices: Nutmeg, clove, cinnamon, tamarind, allspice, kokum, curry leaf
- ★ Minor tree spices: Blimbi, carambola
- ★ Herbal spices: Basil, rosemary, thyme, horseradish, garlic, sage, oregano

Classification based on useful part:

- ★ Whole fruit: Allspice, black pepper, chilli, cumin, fennel, Ajowan
- ★ Bark: Cinnamon, cassia
- ★ Aril: Mace of nutmeg
- ★ Unopened flower Bud: Clove
- ★ Tripartite funnel shaped stigma/ stigma: Saffron
- ★ Kernel: Nutmeg
- ★ Leaves: Basil, bay leaf, marjoram, sage, curry leaf, rosemary
- ★ Rhizome: Ginger, turmeric, mango ginger, rosemary
- ★ Dried latex: Asafoetida
- ★ Root: Horse radish, angelica
- ★ Seeds/fruits: Aniseed, caraway, coriander, dill, fenugreek, mustard
- ★ Fruit pulp/rind: Tamarind, Garcinia

Basi... of spi...
...mon, cumin, mint, nutmeg
...eaves, coriander, onion, thyme, sage, rosemary
...orse radish, mustard
..., turmeric

Miscellaneous:

Major flavour, taste and colour contributing compounds:

Spices	Predominant flavour, taste and colour compounds
Black pepper	Piperine
Cardamom	α-terpenyl acetate, 1,8-cineole
Chilli	Capsaicin, capsanthin, capsorubin
Turmeric	Curcumin
Ginger	Zingiberene
Coriander	Linalool
Cumin	Cuminaldehyde
Fenugreek	Trigonellin
Fennel	Anethole
Cinnamon	Cinnamaldehyde
Clove	Eugenol
All spice	Eugenol
Nutmeg	Sabnene
Star Anise	Anethole
Horse radish	Sinigrin
Basil	Methyl chavicol
Celery	Limonene
Rosemary	Cineol
Thyme	Thymol
Parsley	1, 3, 8-p-menthatreiene
Vanilla	Vanillin
Saffron	Crocin
Asafoetida	Ferulic acid

Colour compounds present in spices:

Colour compounds	Colour	Spices
β-carotene	Reddish orange	Chilli, paprika, saffron, mustard
Cryptoxanthin	Red	Paprika, chilli
Lutein	Dark red	Paprika, parsley
Violaxanthin	Orange	Paprika, parsley
Zeaxanthin	Yellow	Paprika
Capsanthin	Dark red	Paprika, chilli
Capsorubin	Purple red	Paprika, chilli
Crocetin	Dark red	Saffron
Crocin	Yellow orange	Saffron
Neoxanthin	Orange yellow	Parsley
Cucurmin	Orange-yellow	Turmeric
Flavonoids	Yellow	Ginger

B. Spices

A. Major spices:

1.	Black Pepper	2.	Cardamom
3.	Large Cardamom	4.	Ginger
5.	Turmeric		

B. Seed spices:

1.	Coriander	2.	Fenugreek
3.	Cumin	4.	Fennel

C. Tree spices:

1.	Clove	2.	Nutmeg
3.	Cinnamon	4.	Allspice
5.	Tamarind	6.	Curry Leaf
7.	Kudanpuli	8.	Bay Leaf

A. Major spices

1. Black Pepper

King of Spices: *Piper nigrum*: Piperaceae: 2n = 52: Origin: Western Ghats of India

☆ Black pepper (*Piper nigrum* L.) christened as the 'King of Spices'

☆ It is oldest and the most popular spice in the world

☆ India is one of the major producer, consumer and exporter of black pepper in the world

☆ Black pepper is a humid tropic crop it requires high rainfall and humidity

☆ Perennial climbing vine

☆ Ideal annual rainfall: 125-200cm

☆ Type of flower: protogyny

☆ Wild forms usually dioecious but most cultivated ones are gynomonoecious

☆ Inflorescence type: Catkin

☆ Fruit type: Single seeded berry

☆ Pepper is naturally self-pollinated crop due to presence of geitonogamy

☆ Geitonogamy: The transfer of pollens from the anther of one flower to the stigma of another flower in the same plant

☆ Type of pollination: Hydrophily

☆ Edible portion: Fleshy pericarp and hard endocarp

☆ Based on growth habit 5 types of stem:

- ✦ Fruiting branches (Plagiotropes): It grow laterally, produces spikes or fruits
- ✦ Top shoots (Orthotropic): It grow vertically, profuse branching and large number adventitious roots
- ✦ Hanging shoots (Geotrophic): Geotrophical growth pattern

☆ Ancestor of black pepper: *P. wightii* and *P. galeatum*

☆ *P. nigrum* is a tetraploid 2n=4X=52 whereas hexaploid species: 2n=6X=52: e.g. *P.betle*

☆ Highest productivity in the world: Thailand (4089 kg/ha)

☆ Highest production share: Kerala (90%

☆ Highest productivity in India: Karnataka 1kg/vine

☆ Pepper grown as a monocrop (Large scale) as well as mixed crop (Coconut, Arecanut, Jack fruit)

☆ Suitable intercrop in coffee estates

☆ For commercially propagation mainly cuttings selected from: Runner shoots

☆ Runner shoots originate from the base of the vine and creep on the ground, have long internodes which strike roots at each node

☆ Cuttings taken from middle of 1/3rd of the shoot

☆ Bush pepper is propagated by plagiotrophic shoots

☆ Trench method: A simple, cheap and efficient technique for propagation of black pepper

☆ Pepper rapid multiplication technique was developed by IISR, Calicut

☆ Rapid multiplication ratio: 1:40

☆ Bush pepper means by planting lateral branches (plagiotropes) of pepper, the vine can be grown as a bush

☆ Standard trees for pepper cultivation: *Erythrina* spp., *Garuga pinnata*, *Grevillea robusta* (silver oak), *Alianthus malabarica* (Matti)

☆ Lowering of the vines: vines are allowed to trail on support trees up to 1.5 m(induction of more leader shoots covering the entire standard tree)

Cultural practices

- Lopping: done for regulation of shade, it provides optimum light to the vines and standard trees to grow straight
- Lopping is done at 4th year onwa... ...June and September)
- Cover crops used in ... (West coast regio...

- Cover crops effective soil cover to prevent soil erosion during rainy season (summer dry leaves act as organic mulch)

☆ Spacing: 2.7 m×2.7 m = 1100 vines/ha (Mono-cropping system)

☆ Majority of the cultivated varietal types are monoecious

☆ Karimunda is the most popular cultivar in Kerala

Varieties	Breeding methods	Special features
i. Pepper Research Station, Panniyur, KAU, Kerala		
Panniyur 1	Hybrid (Uthirankottah × Cheriyakania Kadan)	Bold berries
anniyur-2	OP seedlings of Balankottah	Tolerant to shade
anniyur-3	Hybrid (Uthirankottah × Cheriyakania Kadan)	
nniyur-4	Selection from Kuthiravally type II	-
niyur-5	OP progeny of Perumkodi	Suitable for mixed cropping, Tolerant to shade
iyur-6	Clonal selection from Karimunda	
iyur-7	Open pollinated progeny of Kalluvally	
yur-8	Hybrid, Panniyur 6 × Panniyur 5	Tolerant to Phytophthora foot rot and drought
lian Institute of Spices Research (IISR), Kozhikode, Kerala		
ra	Selection form Karimunda (KS-14)	-
ara	Selection form Karimunda (KS-27)	-
an	A natural triploid (2n =3X=78)	-
	-	Suitable for industrial extraction of oils and oleoresins
di	-	Tolerant to Foot rot (*Phytophthora*)
a	-	Suitable for most of the black pepper growing areas
	A selection from Aimpiriyan col[illegible]0	-

Pournami	A selection from Ottaplackal coll. 812	Tolerant to root knot nematode
IISR Malabar Excel	HP 813 (Cholamundi × Panniyur-1)	Suitable for high altitude
IISR Girimunda	HP 105 (Narayakodi × Neelamundi)	Suitable for high altitude
IISR Thevam	-	Suitable for high altitude areas of South India
IISR Shakti	OP seedlings of Perambramundi (P24)	Tolerant to *Phytophthora*

☆ Pepper normal flowering time: May-June with the onset of the south west monsoon

☆ Duration of flowering to fruiting : 6 months

☆ Full bearing stage of vine: 7-8 year after planting

☆ Pepper vine starts yield from 3-4th year of planting

☆ Pepper vines yield decline starts after 20-25years

☆ Pepper fruit setting percentage: 50%

☆ Spike shedding percentage: 14-65%

☆ Reduction of spike shedding IAA @ 50 ppm at berry setting stage

Harvesting stage:

Products	Products Maturity at harvest
White pepper	Fully ripe
Black pepper	Fully mature and nearly ripe
Canned pepper	4–5 months after fruit set
Dehydrated green pepper	10–15 days before full maturity
Oleoresin, Oil	15–20 days before full maturity
Pepper powder	Fully mature with maximum starch

☆ White pepper: Prepared by removing the outer skin, it is done before drying the berries

☆ Harvesting season: December- January (Plains) and January-April (Hills)

Maturity Index:

♣ Black pepper: Fully mature and 1-2 berries start[illegible] yellow[illegible] spike

♣ White pepper: Fully riped

- High quality black pepper obtained blanching berries
- Dried berries the moisture content: below 10%, if more than 12 severe fungus infection
- Sun drying is the best method of drying

Bush pepper

- Rooted lateral branches grown as bushes are known as bush pepper
- Raised as a potted bushes or field grown bushes
- Bush pepper yield: 100–150g of dry pepper per pot/year
- It yields throughout the year, yield up to 1 kg after 3 years of planting

☆ Average yield of pepper: 800-1000 kg/ha

☆ Dried pepper contains below 10% moisture content

☆ Drying recovery:

- Black pepper: 33%
- White pepper: 25%

☆ The average dry recovery varies between 33-37%

White pepper

- It is obtained by removing the outer part of the pericarp of the ripened berries
- Prepared from retting (with frequently changing of water) fully ripened red berries for 7-8 days followed by removal of outer skin by washing and drying
- White pepper is also prepared by fermentation using matured green bepper and black pepper

☆ Starch accounts for 34% and 56.5% in black pepper and white pepper respectively

☆ Moisture Content is reduced from 82.5% at pin head stage to 60 and 40% at ripening stage of black pepper

☆ Pungency in black pepper is due to piperine

☆ Average content of piperine in berry:1.7–7.4%

☆ Volatile oil is responsible for the aroma and flavour

☆ Oleoresin is produced by solvent extraction of pepper powder

☆ Aroma of pepper is due to 2-5% volatile oil-Immature pepper has more volatile oil content

☆ In pepper cultivars the essential oil content reported was 0.4-7% and piperine content was from 2-7.4%

☆ Bitter taste of black pepper is due to 3-6% piperine (alkaloid)

☆ Formula for piperine: $C_{17}H_{19}O_3N$

☆ Green colour of pepper should be maintained by minimum salt level 12%

☆ Treatme[illegible]ith SO_2 [illegible] green pepper

☆ Spike sh[illegible] lac[illegible]ection

☆ Indian Institute of Spices Research (IISR), Kozhikode (Calicut), Kerala- established at 1995

Pest and diseases

☆ Pepper pollu beetle (*Lanka ramakrishnai*) is a major destructive pest

☆ Root knot nematode (*Radopholus simles*)

☆ Foot rot or quick wilt : *Phytophthora capsici* most destructive of all diseases (severe in rainy season)

☆ Pollu disease or anthracnose: *Colletotrichum gloeosporioides* (Pollu means 'hollow berry')

☆ Stunt disease caused by virus

☆ Slow decline or slow wilt: complex (nematode and anthracnose)- major problem

☆ Pepper yellows/ slow decline complex disease caused by the burrowing nematode (*Radopholus similis*) and *P. capsici*

Major sources of biotic and abiotic stress genotypes:

Features	Resistant sources
Tolerant to foot rot	Balankotta, Kalluvally, Narayakkodi, Neelamundi, Uthirancotta
Tolerant to slow decline *(Meloidogyne incognita)*	Pournami
Tolerant to Pollu disease	*P. barberi, P. chaba, P. hymenophyllum, P. longum*
Adaptable to high elevation	HP 34, HP 105, HP 812, HP 728, HP 105, HP 813
Tolerant to drought	KS 51, KS 69, KS 114, Panniyur-5
Medicinal value	*P. longum, P. mullesua, P. betle, P.chaba*
Ornamental value	*P. crocatum, P. magnificum*
Essential oil	Balankotta, Kottanadan, Kumbhakodi
Oleoresin and Piperine	Kottanadan, Kumbhakodi
High oil content	Balankotta and Subhakara

2. Cardamom

2. **Queen of Spices/True Cardamom:** *Elettaria cardamomum*; Zingiberaceae; $2n = 48$; Origin: Western Ghats

★ Cardamom is a herbaceous perennial bushy herb with underground (subterranean) and aerial leafy stems (tillers) made of leaf sheaths

★ Cardamom is commercially cultivated for its dried fruits (capsules)

★ Highly prized spices in the world

★ Oldest known spices in the world
★ Shade loving plant (Pseophyte)
★ Cardamom belongs to the order Scitaminae
★ Humid tropical climate is ideal for cardamom cultivation
★ Most expensive spices in the world
★ Guatemala emerged as world's premier producer and exporter of cardamom (90%) in the global trade
★ India is the second largest consumer of cardamom in the world after Saudi Arabia
★ Guatemala is the major competitor in production
★ Kerala accounts for 60% of the cultivated area in India
★ Inflorescence type: Long panicle arising from the underground stem
★ Cardamom has bisexual flowers, self compatible but cross-pollination is more common
★ Type of pollination: Cross pollination
★ Mode of pollination: Honey bees (*Apis cerana indica*)
★ Micropropagation is ideal for generating true to type and virus free planting material from high yielding clones
★ Rainfall distribution is necessary for panicle initiation during the month of February to April
★ The development of reproductive buds (panicles) takes place in about 10 to 12 months
★ The peak flowering is spread over a period of six months from May to October.
★ The time required to reach full bloom stage from flower/bud initiation ranges from 26 to 34 days
★ For cardamom quick and higher germination seeds are treated with 2.5% nitric acid for 10 minutes
★ Propagation: Suckers (most preferred method)
★ Sucker multiplication during: March to September
★ Trench system of planting is generally preferred
★ Rapid clonal multiplication was developed by IISR, Calicut
★ 1 kg of seed capsules (500-800 fruits) produces 3000-5000 seedlings
★ Acid scarification with 25% nitric acid for 10 minutes: increases the germination percentage

Fast growing shade trees (planted for to protect the seedlings from direct sunlight.)

♣ Dadap (*Erythrina lithosperma*), Albizia, Karuna (*Vernonia arborea*), Corangati (*Acrocarpus fraxinifolius*)

♣ Chandana Viambu (*Toona ciliata*), Njaval *(Syzygium cumini*), Jack tree (*Atrocarpus heterophyllus*)

★ Shade regulation done during the months of March-April (pruning branches of shade trees to provide 40 - 60% filtered light)

★ Capsule development takes about 110 to 120 days from the full bloom stage
★ Common shade trees in cardamom: Jack, Red cedar, Karimaram, Pulangi, Elengi
★ Mulching is important cultural practices in cardamom
★ Trashing is the removal of old and drying shoots once in a year done in onset of monsoon
★ Based on the adaptability, nature of the panicle, shape and size of fruits, the cultivated cardamom is grouped into 3 botanical varieties viz. Malabar, Mysore and Vazhukka
★ **Types or Variants:**
1. *Elettaria cardamomum* var. *major* (includes wild indigenous types)
2. *Elettaria cardamomum* var. *minor* (Three cultivated types)

Types	Varieties
Mysore (High Altitudes)	Coorg Cardamom Selection 1(CCS-1), ICRI-1, ICAI-2
Malabar (Low Altitudes)	Mudigree-1, PV-1, SKP-14, Appangala-1, Appangala-2, IISR Vijetha, IISR Avinash, ICRI-1, 3, 4, 5, 6, Mudigere 1, 2, 3
Vazhukka (Wider range)	PV-1
Appangala-1	Suitable for intensive cultivation (monocrop and mixed crop conditions)
Appangala-2	Resistant katte virus, Cardamom mosaic virus
IISR: Coorg Suvasini	-
IISR: Vijetha	Resistant katte virus, Cardamom mosaic virus
IISR: Avinash	Resistant to rhizome rot
Suvasini	Kodagu Cardamom type
PV-1	Long and bold capsules
CCS-1	Suitable for high density planting (HDP)
Other varieties: PV-2, Mudigere-1, Mudigere-2, ICRI-1, ICRI-2, ICRI-3, ICRI-4	

★ Malabar cultivar bears prostrate panicle (panicles spreading on ground)- popular in Karnataka
★ Mysore, characterized with erect panicles (grown in Kerala and TN)
★ Vazhukka (Mysore × Malabar), semi erect panicle : popular in Kerala
★ ICRI-4: Suitable for lower Palani hills
★ Peak period of harvest is October-November
★ Average yield of dry capsules: 500 k...
★ Economic age of plantation: ...
★ Major constituents for ca...
★ Volatile oil content o...

★ Most of cardamom varieties contain 5-9% oil

★ Curing temperature for cardamom: 50°C (moisture of freshly harvested capsules reduced from 8-12%)

★ Curing temperature 40–45°C @ 10–12 hrs maintained during all the stages of drying which helps in good retention of green colour

★ Generally cured cardamom have 12% moisture

★ Flue curing: 45–50°C @ 18-22 hrs. It is one of the best methods of drying (getting high quality green cardamom)

★ Bleached cardamom:

✦ Prepared by using SO_2, KMS (25% containing 1% HCl for 30 min) and H_2O_2 (4–6% at pH 4.0)

Pest and diseases

♣ Leaf spot: *Phyllosticta elettariae*-destructive disease in nurseries

♣ Mosaic or Katte viral disease is transmitted by aphids (*Pentalonia caladii*))

♣ Azhukal or capsule rot: *Phytophthora nicotianae* var. *nicotianae* and *P. meadii*

♣ Rhizome rot or clump rot: complex soil borne disease

♣ Leaf blight ('Chenthal') is caused by *Colletotrichum gloeosporioides*

♣ Cardamom thrips is the most destructive and persistent pest of cardamom

♣ Shoot and capsule borer: *Conogethes punctiferalis*: dead heart symptoms

Cardamom Research undertaken in India:

♣ ICAR-Indian Institute of Spices Research, Regional Station, Appangala, Karnataka

♣ Indian Cardamom Research Institute (ICRI), Myladumpara, Idukki, Kerala

♣ Cardamom Research Station (Kerala Agricultural University), Pampadumpara, Idukki, Kerala

♣ Regional Horticultural Research and Extension Centre, University of Agricultural and Horticultural Sciences, Mudigere, Karnataka

2.2. Large cardamom/Nepal cardamom: *Amomum subulatum:* Origin: Eastern Himalayas

★ Commercially propagated by suckers

★ **Varieties**: Bebo, Ramla, Ramsey, Golsey

★ Chirkey disease: Transmitted by aphids (*Brachycaudus helichrisi, Rhopalosiphum maidis)*

★ Forkey disease: Transmitted by aphids *(Micromyzus kalimpongensis)*

3. Ginger

3. **Ginger**: *Zingiber officinale*: Zingiberaceae: 2n=22: Origin: South East Asia

★ Ginger is an herbaceous perennial, having underground branched rhizome with small scales

★ Rhizomes used as a spice

★ Ginger: exhaustive crop (it is not desirable to grow ginger in the same soil year after year)

★ Ancient and major spice in the world

★ India is the largest producer of dry ginger in the world contributing to the tune of about 30% of the world's production

★ Jamaican ginger is considered to be the best in the world trade (2nd Indian ginger)

★ Major pungent principle of ginger: Gingerol

★ Type of inflorescence: Spike

★ Ginger is propagated by portions of rhizomes known as seed rhizomes

★ Seed rhizome: 2.5-5.0 cm length weighing 20-25 g each having one or two good buds

★ Seed rate: 1500-1800 kg/ha

★ Ginger requires 1300-1500 mm of water during its crop cycle

★ Cultivated as a rainfed crop in high rainfall areas

★ Ginger attains full maturity in 210-240 days (7-8 months) after planting

★ Vegetable purpose: after 5-6 months

★ Moisture content: Fresh ginger: 80-82%, Storage purpose:10%

★ Yield of dry ginger: 19-25% of fresh ginger

★ Recovery of dry ginger: 16-18%

Varieties:

Varieties	Specific features
IISR: Suprabha, IISR: Suruchi	A clonal selection from Kunduli Local
IISR: Mahima, IISR: Rejatha	High oil content
IISR: Varada	Most promising varieties among other varieties of ginger, tolerant to rhizome rot
Suruchi, Suprabha and Suravi Subhada	High dry recovery
Rio-de-Janeiro	Most popular variety among the farmers
Rio-de-Janeiro and Maran	Highest oleoresins
Karakkal	Highest essential oil
Surari	X-ray induced mutant of
Himagiri	Best for green ginger

Indigenous Ginger types	Maran (Assam), Kuruppampadi, Ernad & Wyanad Local (Kerala)
Dry Ginger varieties	Himachal, Maran, Mananthody and Kuruppampadi
Raw Ginger Varieties	Rio-de-Janeiro, China Wynad and Varad

★ *Average yield: 15-25 t/ha*

★ *Fibre content of Ginger: 5.19%*

★ *Ginger oil (0.5%-3.0%) possesses only aroma and not the flavour of spice*

✦ *Unbleached ginger : Peeled rhizomes washed and sun drying*

✦ *Bleached ginger: Peeled rhizomes soaked in slurry of slaked lime, Ca(OH)2, 2% in water for 6 hrs (1 kg of slaked lime/120 kg of water)*

★ *Oleoresin content in ginger: 3.5-9.5%*

★ *Drying recovery: 16-18%*

★ *Dry ginger is harvested between at 6-7 months after planting*

Pest and diseases

♣ *The shoot borer (Conogethes punctiferalis) is the most serious insect pest*

♣ *Rhizome scale (Aspidiella hartii) infests rhizomes in the field (at later stages) and in storage*

♣ *Leaf roller: Udaspes folus*

♣ *Major pest during storage: Cigarette beetle (Lasioderma serricone)*

♣ *Soft rot/rhizome rot: Phythium spp- soil borne disease*

♣ *Bacterial wilt caused by Ralstonia solanacearum Biovar-3 is a soil and seed borne disease*

Cardamom Research undertaken in India:

▪ *ICAR-Indian Institute of Spices Research, Kozhikode, Kerala*

▪ *High Altitude Research Station, OUAT, Pottangi, Orissa*

▪ *Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh*

▪ *Kerala Agricultural University, Thrissur, Kerala*

4. Turmeric

4. **Turmeric:** *Curcuma longa*: Zingiberaceae: 2n =3X = 63: Origin: South East Asia

★ *Turmeric is the dried underground rhizome of perennial herbaceous herb*

★ *It is used as a condiment, dye, drug and cosmetic in addition to its use in religious ceremonies*

★ *Curcumin is the golden-yellow pigment present in turmeric. It is used at levels of 5–20 ppm.*

★ India is a leading producer and exporter of turmeric in the world

★ Andhra Pradesh occupies 38.0% of area and 58.5% of production of turmeric cultivation in India

★ Indian turmeric is considered to be the best in the world, about 90% of the total produce is consumed in India

★ Shade loving condiment crop

★ Turmeric as a best component crop in agri-horti and silvi-horti systems

★ Hydrated lime @ 500 - 1000 kg/ha has to be applied for laterite soils based on the soil pH and thoroughly ploughed

★ Curcumin (4-7%) is the principle colouring pigment in turmeric

★ Curcumin is used as therapeutic effects and anti-cancer property

★ Commonly used shade crops for turmeric cultivation: Castor, Agathi (*Sesbania grandiflora*)

★ Processing 3 steps: Curing => Polishing => Colouring

★ Average curcumin content in rhizomes 1.8 to 5.5%

★ Optimum sowing time: May-June or July-August

★ Essential oil content: 2.5 to 7.2%

4 important species:

Common name	Scientific name	Special features
Kasturi Manjal/Cochin turmeric	*Curcuma aromatica*	Used in medicine and in toiletry articles
East Indian arrowroot	*Curcuma angustifolia*	High starch content in rhizomes
Mango ginger	*Curcuma amada*	Rhizomes contain mango flavour and taste
White turmeric	*Curcuma zedoaria*	Used in perfume industry

Varieties:

IISR Varieties	Krishna
Suvarna	Sugandham
Suguna	Rajendra Sonia
Sudharsana	
IISR Prabha	
IISR Prathibha	

IISR Alleppey Supreme	
IISR Kedaram	
TNAU varieties: Co-1, BSR-1, BSR-2	
High Altitude Research Station, Pottangi, Odisha varieties	
Ranga, Rasmi (Rajpuri Local)	-
Roma, Suroma, Surangi	-
KAU Varieties	
Kanti, Sohba, Sona, Varna	

Specific features of varieties:

IISR: Suranjana	Tolerant to rhizome rot and leaf blotch; resistant to rhizome scales
IISR: Rajapuri	Resistant to leaf spot and susceptible to blotch and rot
IISR: Kedaram and Tekurpet	Tolerant to leaf blotch
IISR: Suguna and IISR: Sudarshana	Field tolerant to rhizome rot
Alleppey	High colour variety
Armor, Tekurpet and Mydukur	Long duration variety (9 months)

Mutant varieties:

Varieties	Sources	Special features
CO-1	Mutant (X-ray) selection from Erode local	Suitable for drought prone areas
BSR-1	Mutant (X-ray) selection from Erode local	Suitable for drought prone areas
BSR-2	Mutant (X-ray) selection from Erode local	Resistant to scale insects
Suroma	Mutant (X-ray) selection from Tsundur	Field tolerant to leaf blotch, leaf spot

★ Other varieties: Sugandham, Rajendra Sonia
★ Seed rate: 2500 kg/ha (35-45 g of weight)
★ Transplanting technique in turmeric developed using single bud sprouts (about 5 g)
★ Turmeric can be grown as an intercrop in coconut and arecanut plantations

★ Average yield of green turmeric 25-25 tonnes/ha
★ Boiling is the first post-harvest operation
★ Fingers: lateral branches or secondary 'daughter' rhizomes
★ Bulbs: Central 'mother' rhizomes
★ Splits: bulbs that have been split into halves or quarters
★ Turmeric contains 3-5% volatile oil is obtained by steam distillation of turmeric powder for about 8-10hr
★ Drying recovery: 20-25%
★ Yield of oleoresin :7-15%

Pest and diseases

★ The shoot borer (*Conogethes punctiferalis*) is the most serious pest in turmeric
★ Turmeric leaf blotch: *Taphrina maculens*
★ Rhizome rot (*Pythium graminicolum*) is the most serious disease
★ Leaf spot (*Colletotrichum capsici*) and leaf blotch (*Taphrina maculans*) are the serious foliar disease

B. Seed Spices

✦ Seed spices are annual herbs, whose dried seeds or fruits are used as spices.
✦ Seed spices: nature's gift to humankind
✦ Seed spices "High value low volume crops" are the most remunerative commodities of the arid and semi-arid regions of India
✦ Out of the total 63 spices grown in India, 20 are classified as seed spices
✦ The 90% of the total seed spices that we produce and export only 10% of our production to the world
✦ The share of seed spices export to total spices is only 18% in terms of quantity
✦ India is the largest producer, consumer and exporter of seed spices and their products
✦ Rajasthan and Gujarat are the pre-dominant states growing a seed spices as a commercial scale and hub for the seed spices it occupies about 80% of the seed spices cultivated in India
✦ Major seed spices in India: cumin, coriander, fenugreek, fennel
✦ Leading export share and value seed spices: Cumin
✦ Suitable spice for eroded soils: Dill
✦ Suitable for nutritionally eroded soil: coriander, cumin and fenu
✦ National Research Center for Seed Spices (NRCSS), Ajmer,

1. Coriander

1. **Coriander:** *Coriandrum sativum*: Apiacae: Origin: Mediterranean region
   - ★ Coriander is a rigid, strong-smelling annual herb
   - ★ Coriander has been used as an antispasmodic, carminative, stimulant, and stomachic
   - ★ Black cotton soil is more suitable for coriander rainfed cultivation
   - ★ Bold round type *(C. sativum var. vulgare)*, Small-seeded type *(C. sativum var. microcarpum)* both under cultivation
   - ★ Highly cross pollinated crop (Honeybees) (Adromonoecious flowers)
   - ★ Seed germination: epigeal
   - ★ Coriander leaf smell due to different aldehydic components
   - ★ Heterophylly (existence of two or more morphologically different leaf types on the same plant) observed in leaf morphology
   - ★ Seed flavour is due to terpenes *i.e.* linalool
   - ★ Leading producer of coriander: Rajasthan
   - ★ Type of inflorescence: Compound Umbel
   - ★ Dried coriander contains essential oil content: 0.1-1.5%
   - ★ Essential oil contains d-linalool (also known as coriandrol)

Varieties	Breeding methods	Features
Arka Isha	-	High yielding multicut type of coriander
CO-1	Pure Line Selection	Suitable for green and grains
CO-2	Reselection from culture of P2 of Gujarat	Dual purpose
CO-3	Resection from Acc. No. 695	Dual purpose
Swathi	Mass Selection	Suit for late sowing
Sadhana	Mass Selection	Suit for rainfed areas, Res. to aphids & mites
Gujarat Coriander-1	Selection from Local	Grain purpose
Gujarat Coriander-2	Selection from CO-2	Grain purpose and no lodging
Rajendra Swati	Mass Selection	Suit for intercropping-res. to stem gall disease
Rcr-41	Recurrent Selection from UD-41	Suit for irrigated area-Res. to Stem Gall
HAU, Hisar	Hisar Sugandh, Hisar Anand, Hisar Surubhi	
GBPANT	Pant Haritma	
CS Azad	Azad Dhannia	

   - ★ Direct sown crop: Done by broadcasting
     - ✦ Irrigated condition:10-16 kg/ha
     - ✦ Rainfed condition: 15-20 kg/ha
   - ★ Coriander very sensitive to weeding
   - ★ Rainfed sowing time of coriander in Tamil Nadu: September-October
   - ★ Seed soaking, seed splitting, rubbing is necessary for uniform germination
   - ★ Average yield: 400-500 kg/ha (Rainfed) and 600-1200 kg/ha (Irrigated condition)
   - ★ Seed shattering is a major problem after maturity
   - ★ Dried fruits contains moisture content about 8-9%

   Pest and diseases
   - ★ Coriander wilt is caused by *Fusarium oxysporium* (Dropping of leaves, Epinasty)
   - ★ Powdery mildew: (*Erysiphe* polygoni) serious disease in rainfed crop
   - ★ Stem gall: *Protomyces macrospores* is devastating problem in coriander

2. Fenugreek

2. **Fenugreek:** *Trigonella foenum-graecum*: Fabaceae: 2n=16, Origin: Mediterranean
   - ★ Tolerant to frost and freezing weather
   - ★ Rajasthan is the leading producer of Fennugreek
   - ★ Highly self pollinated crop due to cleistogamous flower structure
     - ✦ Common methi: *Trigonella foenum-graecum*- White flower, Straight pods
     - ✦ Kasui methi: *Trigonella corniculata* (Multiple cutting)- Rosette leaves, Long vegetative growth period, Bright orange to yellow, curved or sickle-shaped pods
     - ✦ Blue fenugreek: *Trigonella caerulea*
   - ★ Fenugreek as a chemurgic crop has a wide use for industrial purposes
   - ★ Direct sown crop, Seed rate: 20-25 kg/h
   - ★ Thinning is necessary for fenugreek cultiv

Varieties:

Varieties	Remarks
Co-1	Suit for intercropping and dual purpose
Sindhu	Tolerant to wilt and resistant to aphids
Rajendra Swathi	Resistant to stem gall
Rajendra Kanti (Mass Selection)	Suit for pure and intercropping
Rmt-1	Moderately tolerant to root rot and powdery mildew
Lam Sel.1	High protein (53%) variety
Hisar Sonali	Suitable for greens
Other varieties: Sadhana, Swathi, IARI: Pusa Early Bunching	

★ *Leaf plucking (50%) starts 70-75 days after sowing*
★ *Average seed yield: 1200-1500 kg/ha*
★ *Leaf yield: 800-1000 kg/ha*
★ *Maturity index: 50% seeds turn to yellow colour*
★ *Rootrot (Rhizoctonia solanii) is a serious disease of fenugreek*

3. Cumin

3. **Cumin:** *Cuminum cyminum*: Apiacae: 2n=14: Origin: Mediterranean region
★ *Prefers cool and dry climate*
★ *High humidity and rain leads to leaf blight and powdery mildew disease*
★ *Cumin is not having inherent ability to tolerant against frost*
★ *Cumin volatile oil content: 2.5-3.5%*
★ *Cumin seeds contain high protein (17.7%)*
★ *Weed competition is a major problem in all stages growth*
★ *Seed rate: 8-10 kg/ha*
★ **Varieties**: *RZ-19, RZ-209, RZ-223, RZ-341, GC-2, GC-4*
★ *Serious weed: Zeeri (Plantago pumila); Control: Flucholralin (Pre-emergence) @ 1 kg/ha*
★ *Average seed yield: 450-550 kg/ha*
★ *Leaf blight: Alternaria burnsii is a major disease*

4. Fennel

4. **Fennel**: *Foneiculum vulgare*: Apiaceae: Origin: Mediterranean region
★ Annual herb (Biennial with potency of regeneration)
★ Crop duration 5-6 months
★ Volatile oil: 0.7-1.2%
★ Frost damage is minimised by 0.1% sulphuric acid, creating smoke cover, using windbreaks
★ Direct sowing: 9-12 kg/ha
★ Transplanting 3-4 kg of seeds raised in 100m^2 nursery 5-6weeks old seedlings used
★ **Sowing season:**
  ✦ Plains: October-November
  ✦ Hills: May-June
★ **Varieties**: RF 101, RF 125, RF 35 Gujarat Fennel 1, CO-1-Suitable for hilly regions
★ Thinning is nessary after 20 days of sowing
★ Chewing type fennel (Lucknawi) is harvested at 30-45 days after pollination
★ Average yield: 900-1000 kg/ha
★ Fennel is highly affected by Remularia blight

3. Tree Spices

Tree Spices:
★ **Clove, Nutmeg, Cinnamon, Allspice, Cassia, Tamarind, Bay leaf, Curry leaf**

1. Clove

1. **Clove**: *Syzygium aromaticum*: Myrtaceae: Origin: Indonesia
★ Economic part: Unopened flower bud
★ Tropical evergreen tree, grown in humid tropics
★ Clove is suitable for mixed cropping in coconut and arecanut gardens
★ Type of fruit: Single seeded drupe
★ Fruit of seed collection is known as mother of cloves
★ Propagation: Seeds
★ In Indonesia Clove is most used for making KRETEK cigarette industr
★ Problem in clove: Alternate bearing habit
★ Clove trees starts yield on 7-8 year after planting

★ Full bearing stage clove attains after 15 years
★ Harvesting stage: Unopened flower bud begin to turn pink colour
★ Average annual yield: 2 kg/tree
★ 1kg of clove contains 11,000 to15,000 dried cloves
★ Clove oil contains 70-80% of free eugenol and 5-12% of eugenyl acetate
★ Leaves oil content: 1.5-1.8% oil
★ Stem oil has 5–7% oil (70-90% eugenol)
★ Bud oil (17%) is superior in odour and flavour to stem oil and leaf oil
★ Clove bud oil contains 85% eugenol
★ Methyl-n-amyl ketone: Present only in bud oil
★ Volatile oil content of oleoresin is usually 70–80%

2. Nutmeg

2. **Nutmeg**: *Myrisitica fragrance*: Myristicaceae: 2n=42, 44: Origin: Indonesia
★ Evergreen dioecious tree
★ Nutmeg is the dried kernal of seed
★ Mace is the dried aril surrounding the seeds
★ Introduced to India by the colonial rulers during the 18th century
★ Fleshy pericarp- Used for making pickles, jams, jellies
★ Flowers are structurally hermaphrodite but functionally dioecious
★ Nutmeg trees flower throughout the year
★ Type of pollination: Cross
★ Pollinators: Wind and Insects
★ Type of fruit: Drupe
★ **Variety**: Konkan Sugandha (Selection from VLG-26)
★ **Varieties**: Viswasree, IISR Keralashree
★ Propagation: Seed
★ For multiplication of nutmeg, epicotyl grafting developed by NRCS, Calicut
★ 65% of female trees is necessary for optimum yield in nutmeg orchards
★ Nutmeg contains 25-50% fat (Major constituent-highly aromatic-Trymyristicin)
★ Major constituent is trymyristicin
✦ Nutmeg oil: 7–16% (Aromatic ethers, myristicin and elemicin are present in oil and oleoresin)
✦ Mace oil: 4–17%
★ Tree starts flowering 7-8 years of planting

★ Straight growing shoots-orthotropic or chupon-used as scion to get normal shape
★ Plagiotropic shoots (Lateral branches)-Used for a shrubby spreading plant
★ Problem in nutmeg:
✦ Segregation of Seedling into 1:1 ratio Male & Female trees
✦ Due to 50% of unproductive trees
★ Planting female and male trees in nutmeg:10:1
★ Top working: Unproductive male plants converted into productive female trees by grafting or budding
★ Orthotropic shoots from female trees used as a scion
★ Full bearing stage 15-20 years
★ Yield: Nutmeg: 800 kg/ha; Mace: 100 kg/ha
★ One tree can produce 2000-3000 fruits/tree
★ The proportion of dried shelled nutmeg to dried mace: 20:3

3. Cinnamon

3. **Cinnamon**: *Cinnamomum sp.*, Lauraceae: Origin: Srilanka
★ Cinnamon is hardy plant
★ Edible part: Bark
★ Srilanka is the largest producer of cinnamon bark
★ Mainly cultivated as a Rainfed crop
★ True Cinnamon or Sri Lankan Cinnamon is the dried inner stem bark of *Cinnamomum verum*
★ Earliest known spices
✦ True cinnamon also called sweet wood (*Cinaamomum verum*)
✦ False cinnamon/Chinese cinnamon/bastard cinnamon (*Cinnamom cassia*)
★ Oleoresin content in cinnamon: 7-10%
★ Indian cassia/Tejpet is popular in Northern India
★ Cinnamon Bark has 0.5-2.5% oil (75% Cinnamaldehyde & 5-10% Eugenol)
★ **Important economic species of cinnamon:**

Common name	Botanical name	Co…	…ic part
Chinese cassia	*C. cassia*		
Indonesian cassia			
Saigon cassia			
Indian (Tejpe…			

★ Major constituent of cinnamon leaf oil: Eugenol
★ Major constituent of cassia leaf oil: Cinnamaldehyde
★ Saigon cinnamon has 1-5% essential oil in content and 25% cinnamaldehyde in essential oil, which is the highest of all the cinnamon species.
★ Common method of propagation: Seeds
★ **Varieties:** IISR-Navashree, IISR-Nithyashree, Konkan Tej, YCD-1, KAU: Sugandhini
★ Bark is used to extract oil and oleoresin
★ Bark oil has highest cinnamaldehyde content whereas leaf oil high eugenol
★ Cinnamon bark is extracted generally after the rains at the time when the red flush of young leaves turns green and their sap flows freely
★ Cinnamon has 7–10% oleoresin
★ Bark oil content: 0.5–2.5% (65% Cinnamaldehyde)
★ Leaves oil content: 5-15% oil (eugenol-70–80%). It is used in dental preparations and synthetic vanillin
★ Coppicing is done 2 year old trees for encouraging of side shoots from the stump
★ Test cut is done for determining the time of bark peeling
★ Cinnamon knife is developed by Horticultural Research Station (HRS), Thadiyankudisai, Tamil Nadu
★ Quillings grade: broken pieces and splits of all grades of cinnamon quills
★ Featherings: feather like pieces of inner bark consisting of shavings and small pieces of bark left over
★ Cinnamon chips: Rough unpeelable barks scraped off from the thicker stems
★ Grades of cinnamon bark: Scraped chips, unscraped chips
★ Finest quality grade: 00000
★ Coarsest quality grade: 0
★ Average yield: 200-300 kg/ha (Dried barks)

4. Allspice

4. **Allspice/Sarvasuganthi**: *Pimento dioica*: Myrtaceae: Origin: West Indies
★ Allspice is the dried berry
★ Allspice: aromatic stimulant and a carminative property
★ Dioecious evergreen tree
★ Economic part: Dried immature fruits
★ Allspice name derived from blending flavours of Clove + Nutmeg + Cinnamon
★ All spice has about 3-4% of aromatic steam volatile oil

★ Leading producer is Jamaica
★ Propagation: Seeds
★ Average yield: 50-60 kg/ha (Dried berries)
★ Berry oil content: Eugenol 65%
★ Dried berries are a major item of commerce
★ It has 3-4% of aromatic steam volatile oil
★ Main components of allspice is eugenol (60-75%)

5. Tamarind

5. **Tamarind**: *Tamarindus indica*: Fabaceae: 2n=24: Origin: Tropical Africa
★ Prefers tropical and subtropical climate
★ Contains tartaric acid (8%)
★ Propagation: Seeds and approach grafting
★ Varieties: PKM-1 (Cluster bearing habit-Pulp recovery 39%), Urigam (Long podded-more than 20cm)
★ Red fleshed tamarind is identified at Horticultural College and Research Institute, Periyakulam, TNAU
★ Sweet tamarind is considered as Indian date (Dessert fruit)
★ Sweet tamarind origin: Thailand
★ Sugar content of sweet tamarind: 57.4g/100g

6. Curry Leaf

6. **Curry leaf:** *Murraya koenigi*: Rutaceae: 2n=18: Origin: Northern India
★ Leaves contain volatile oil: Ksenigin and Flower-Murayin
★ Highly self pollinated crop
★ Polyembryony
★ Fruit type: Berry
★ Ornamental species: *Murraya exotica* (Origin: India)
★ Propagated by seeds
★ **Varieties:**
✦ DWD-1: H
✦ DWD-2
✦ Red
★ Harves
★ Avera

7. Kudanpuli

7. **Kudanpuli/Garcinia**: *Garcinia cambogia:* Guttiferae/Clusiaceae: Origin: Western Ghats of India
   - ★ Evergreen, dioecious tree
   - ★ Processed rind is an excellent substitute for tamarind in cooking
   - ★ Rinds are preserved by rubbing with salt & coconut oil
   - ★ Its contain 10.6% tartaric acid
   - ★ Related species: Kokum: *Garcinia indica* (Punampuli)
   - ★ **Kokum variety:** Konkan Amruta (Selection from Shirgaon): Apple shaped fruit and having long shelf life

8. Bay Leaf

8. **Bay leaf:** *Laurus nobilis:* Myrtaceae: Origin: Mediterranean Region
   - ★ Temperate evergreen tree
   - ★ Propagation: Cutting or layering
   - ★ Leaves oil content: 3%

C. Condiments

A. CONDIMENTS
1. Saffron
2. Asafoetida
3. Vanilla
4. Paprika
5. Garlic

B. Other Spices:
1. Betel vine

C. Herbal Spices

A. CONDIMENTS

1. Saffron

1. **Saffron:** *Crocus sativus*: Iridaceae: 2n=3X=24: Origin: Greece or Iran
   - ☆ Economic part: Dried (Strikingly dark red or orange tripartite funnel shaped) stigma
   - ☆ Perennial herb with globular underground corm
   - ☆ Flower colour: Bluish violet (Pungent smelling) borne singly (used as religious rituals)
   - ☆ As precious as gold because of its low production and high demand
   - ☆ Royal position among all other spices
   - ☆ Major producer in the world: Iran
   - ☆ 90% of the world production: Iranian saffron
   - ☆ Used to colour foods even @ 1ppm which gives distinct yellow tinge
   - ☆ Essential oil content: 0.5-1.0%
   - ☆ Main principle is cicrocrocin
   - ☆ In India, it is cultivated only Kashmir
   - ☆ Low annual rainfall @ 35-45cm is desirable
   - ☆ Propagation: Corms (Planted in August)
   - ☆ Flowering time: End of October
   - ☆ About 1.5million flowers on drying gives 1kg
   - ☆ Yield: 160kg of fresh flowe
   - ☆ Drying percentage: 20

☆ Finest, purest and most expensive saffron: Shahi saffron (Golden coloured styles)

2. Asafoetida

2. **Asafoetida:** *Ferula asafoetida*: Apiaceae: Origin: Mediterranean region
   - ☆ Perennial, dioecious plant
   - ☆ Major constituents: Resin (40-60%), gum (25%), volatile oil (10-17%)
   - ☆ Rhizome produce 2 types of plants:
     - ♣ Male: Producing inflorescence
     - ♣ Female plant: Only foliage and no inflorescence
   - ☆ Female plants produce an exudation of thick and paste sap from underground rhizome
   - ☆ Right stage for tapping the rhizomes for asafoetida: Green foliage to turn yellow
   - ☆ Tapping is done for extraction of oleogum

3. Vanilla

3. **Princes of Spices:** *Vanillia planifolia*: Orchidaceae: 2n=32: Origin: Sothern Mexico
   - ★ It is an orchid
   - ★ Vanilla, a vine, is a member of the orchid family
   - ★ It is a climbing monocot, possessing a stout, succulent stem and short-petioled, oblong-lanceolate leaves about 20 cm long
   - ★ Vanilla is considered to be the greatest contribution of the Americas to the world of flavours
   - ★ Shade loving plant, climbing vine
   - ★ Secondary hemi-epiphytes
   - ★ Thermophilous crops
   - ☆ Vanillin (**2-2.5%**) the main flavouring chemical of vanilla
   - ☆ There are two important species
     - ✦ Mexican vanilla: *Vanilla planifolia*: Producing short thick pods
     - ✦ West Indian vanilla: *Vanilla pompana*: Producing largest pods (10-23cm)
     - ✦ Tahitian vanilla: *V. tahitensis*
   - ☆ Vanilla is a tropical crop that thrives best in warm and moist climate
   - ☆ Optimum temperature for cultivation: 25-32°C
   - ☆ Propagation: Stem cuttings (2–3.5 m long)
   - ☆ Aerial roots are formed in nodes
   - ☆ Stamen and pistil united with petals modified lip like structure is called labellum

☆ Self-pollination prevention (physical barriers to the process of pollination) due to structure
☆ Expert hand pollination, from 1000 to 2000 flowers can be pollinated per day
☆ Flower colour: yellowish, wholly green or white
☆ Mode of pollination: Cross pollination
☆ Pollinating agents: Melapone bees and humming birds
☆ Vanilla, being a shade-loving, climbing vine, needs a structure that will support its vertical growth and provide some canopy to filter intense sunlight
☆ Indian coral tree (*Erythrina orientalis*) were found to be the best shade/support trees for vanilla
☆ Vanilla vine supporting trees:
   - ♣ *Jatropha, Plumeria alba, Casuarina, Erythrina, Glyricidia, Bauhinia*, Silver oak
☆ The peculiar structure of rostellum, hand pollination by hand is the rule for fruit setting
☆ Vanilla flowers only once a year (India: December to February)
☆ Flower (3 sepals & petals) are borne in leaf axils (colour-green)
☆ Artificial pollination is necessary for fruit setting
☆ Success of hand pollination is 85-100%
☆ Ideal time for pollination is 6a.m -1.00p.m
☆ To attain pod full size from fertilization: 6 weeks
☆ Fruit: Capsule (popularly called 'beans' or 'pod' in the vanilla market)
☆ To reach full maturity of bean takes 4-10 months
☆ Optimum time for harvesting the bean: Ripe yellowing from its distal end
☆ Vanillin formation is the result of β-glycosidase action on the glucos… during the process of curing
☆ Vanillin extraction method: Hydro-alcoholic extraction
☆ **Main pollination problem**: Vanilla flower contains complex … of *rostellum* makes natural pollination is impossible
☆ Harvesting stage: turning of blossom end on a pale yellow…
☆ **Processing methods**:
   1. **Peruvi…** …ull)
   2. …

★ Wrapping in blankets (For fermentation & sweating) in the night (Repeating this process for 7-12 days)

- ☆ Most desirable size of beans- 18 to 25cm long
- ☆ Vanillin the main flavouring chemical of vanilla
- ☆ Vanillin content of properly cured beans 2.5%
- ☆ Yield: 300-800kg of cured beans/ha
- ☆ One kilogram of cured beans is derived from about 6 kg of green pods
- ☆ Curing is need for processing
- ☆ During the curing process, this glucoside (glucovanillin) is hydrolysed to form vanillin
- ☆ Root rot: *Fusarium batatis* var. *vanillae* serious important fungal disease
- ☆ Anthracnose (*Calospora vanilla*) is the most serious disease in vanilla
- ☆ Major pest attacks buds and flowering: Bug (*Trioza litseae*)

4. Paprika

4. **Paprika:** *Capsiucm annum*: Solanaceae: Origin: South America

- ☆ Condiment paprika is a variant of Capsicum
- ☆ The colour in paprika is due to carotenoids, namely capsanthin and capsorubin, comprising 60% of total carotenoids
- ☆ Outer pericarp of paprika is the main source of capsanthin and capsorubin
- ☆ Oleoresin contains up to 50% capsorubin
- ☆ Pricinple colouring matter is the carotenoid pigment, "Capsanthin"
- ☆ Red colour is due to capsanthin and capsorubin
- ☆ Yellow colour Zeaxanthin, β-carotene
- ☆ Major portion of colouring matter present in outer fleshy pericarp
- ☆ Inner portion and seeds contain the pungent chemical-Capsaicin
- ☆ Paprika types were developed in Hungary
- ☆ Paprika: High colour pigment with pungent or mild pungent or non-pungent
- ☆ Any non-pungent dried red powder is paprika in international trade
- ☆ Spain is chief producer of paprika
- ☆ Variety: KTPL-19
- ☆ Popular paprika: Hungarian paprika
- ☆ Seed rate is 1kg/ha
- ☆ Most common method used to evaluate paprika colour: ASTS (American Spice Trade Association)
- ☆ Average yield 2000kg/ha

5. Garlic

5. Garlic: *Allium sativum*: Alliaceae: Origin: Southern Europe

- ☆ Allicin: Principle of Garlic has antibacterial properties
- ☆ Powerful drugs against amoebic dysentery
- ☆ Propagated by cloves (Group of small bulbs)
- ☆ Crop duration: 4½ -5 months
- ☆ Normal planting season: June-July and October-November
- ☆ TNAU: Ooty-1-Clonal selection
- ☆ Stage of harvest: Leaves start turning yellowish or browning
- ☆ Field or shade curing: 2-3days
- ☆ Field cured bulbs storage condition: 1-1½ months
- ☆ Dust smoke cured bulbs storage condition: 8-10 months
- ☆ Average yield: 6-8t/ha
- ☆ Storage: 32°F with 60% RH

B. Other Spices

1. Betel Vine

Neglected **Green Gold of India**: *Piper betle*: Piperaceae: 2n=26, 32: Origin: Eastern Malaysia

- ♣ Perennial dioecious creeper
- ♣ Prefers tropical climate
- ♣ Moisture loving and shade tolerant plant

Uses:

- ♣ Deep green heart shaped leaves of betel vine are popularly known as Paan in India
- ♣ In South India, tender leaves are pre… market
- ♣ Chewing stimulent
- ♣ Chemopreventive effects aga…
- ♣ Aroma of betel leaf is due t…
- ♣ Classified into 2 types
  - ★ Pungent
  - ★ Non-pungent
- ♣ The leaves on the bra…

D. Major Diseases in Spices

Diseases	Causal organisms	Remarks
A. Major spices		
1. Black pepper		
Quick wilt/Foot rot	*Phytophthora capsici*	Sudden collapse of vines
Pollu disease/Berry spot	*Colletotrichum gloeosporiodides*	Malformation of berries
Slow decline/Slow wilt	*Fusarium sp., Rhizoctonia sp, Pythium sp., Diplodia sp.,*	Vector: *Radopholus similis Meloidogyne incognita*
2. Cardamom		
Katte disease	*Virus*	Vector: *Pentalonia nigronervosa*
Azhukal capsule rot	*Phytophthora meadii, P. nicotianae var. nicotianae*	
Damping/rhizome rot	*Pythium vexans, Rhizoctonia solani*	
3. Ginger		
Soft rot/rhizome rot	*Pythium aphanidermatum*	Yellowing of leaves
Bacterial wilt	*Pseudomonas solanacearum*	Major disease in Kerala
4. Turmeric		
Rhizome and root rot	*Pythium graminicolum*	
B. Seed spices		
5. Coriander		
Powdery mildew	*Erysiphe polygoni*	Major foliage disease
Grain mould	*Helminthosporium sp, Alternaria sp., Carvularia sp., and Fusarium sp.,*	Storage disease
6. Fenugreek		
Root rot	*Rhizoctonia solani*	
C. Tree spices		
7. Nutmeg		
Dieback	*Diplodia natalensis*	
Thread blight	*Marasmius sp.,*	
Fruit rot	*Diplodia natalensis* and *Phytophthora sp.,*	
8. Cinnamon		
Pink disease	*Corticlium javanicum*	
Seedling blight	*Diplodia sp.,*	
Leaf spot	*Gloeosporium sp.,*	

Chapter – 8 : Medicinal and Aromatic Plants

A. Medicinal Plants

- Aloe
- Dill
- Kalmegh
- Guggul
- Medicinal Yam
- Pyrethrum
- Sarpagandha
- Long pepper
- Indian liquorice
- Medicinal *Solanum*
- Periwinkle
- Indian Ginseng
- Babchi
- Safed musli
- Henbene
- Foxglove
- Opium
- Senna
- Rye Ergot
- Deadly Nightshade
- Psyllium

B. Aromatic Crops

- Ambrettee
- Chamomile
- French Jasmine
- Java cintronella
- Palmarosa Grass
- Screw pine
- Scotch spearmint
- Patchouli
- Scented Rose
- Lavender
- Celery
- Davana
- Indian Basil
- Lemon grass
- Vettiver
- Mints
- Ocimum
- Rose geranium
- Eucalyptus
- Sandalwood

A. MEDICINAL PLANTS

- More than 90% of the formulations under the Indian Systems of Medicine viz. Ayurveda, Siddha, Unani, and Homoeopathy (AYUSH), predominantly contain plant-based raw materials.
- Central Scheme for Development and Cultivation of Medicinal Plants was implemented in 1990/91

Economic parts:

- ☆ Fruits (Senna, *S.viarum*, Datura)
- ☆ Leaves (Senna, Datura, Periwinkle, *Tylophora*)
- ☆ Flowers: (*Butea*, *Bauhinia*)
- ☆ Stems (Liquorice, Ginger, Dioscorea, Costus, Garlic)
- ☆ Roots (Rauvolfia, Periwinkle, Ginseng)
- ☆ Seeds (Isabgol, *Abrus*, Nuxvomica)
- ☆ Bark (Cinchona)

1. **Aloe /First aid medicine plant:** *Aloe vera*: Liliaceae
   - ☆ Perennial succulent plant
   - ☆ The source of the drug: Aloin and C-glucosides (Barbaloin)
   - ☆ *Aloe vera* gel contains a glucomannan: Used as a biogenic stimulators and wound healing hormones
2. **Indian Ginseng/Winter cherry/Ashgand**: *Withania somnifera*: Solanaceae: 2n=48: Origin: India
   - ☆ Prefers subtropical to tropical climate
   - ☆ Economic part: Roots
   - ☆ Uses: Immuno-modulator, Anti-stress, Improve the male potency
   - ☆ Alkaloids: Withaniols (0.13-0.68%): Highest in bark
   - ☆ Major alkaloids: Withanine and Somniferine
   - ☆ Withaferine: Antibiotic and antitumor activities found highest in leaves
   - ☆ Seed rate: 10-12 kg/ha

   Varieties:

   - ✦ JNKVV : Jawahar Ashgand-20, Asgandh-WS -90-134
   - ✦ CIMAP: Poshita

   - ☆ Yield: 600-700 kg of dried roots/ha
   - ☆ Related species: Chinese gingeng (*Panax gingeng*): Araliace
   - ☆ Economic part: Fleshy roots

3. **Dill/Sowa**: *Anethum graveolens* var. *sowa*: Apiaceae: Origin: Mediterranean region
   - ☆ Long day plant
   - ☆ Economic part: Leaves and fruits
   - ☆ Uses: Preparation of grip water for controlling vomit and improving digestion
   - ☆ Leaves: Herb oil (Phellandrene)
   - ☆ Essential seed oil content (2.5-3.0%): Carvone
   - ☆ **Important species:**
     - ✦ European dill: *A.graveolens*
     - ✦ Indian dill: *A. sowa*
   - ☆ Seed rate: 5-10kg/ha
   - ☆ Yield:
     - ✦ Herbage yield: 2.5 to 3.0 t/ha
     - ✦ Seed yield: 1-1.4 t/ha
4. **Babchi**: *Psoralea corylifolia*: Fabaceae: 2n=20, 22: Origin: China
   - ☆ Treatment for leucoderma, leprosy and psoriasis
   - ☆ Economic part: The seed is surrounded by a sticky, oily pericarp
   - ☆ Alkaloids: Coumarins (Psoralen and Isopsoralen)
   - ☆ Type of fruit: Single-seeded pod
   - ☆ Propagation: Seeds
   - ☆ Average dry seed yield: 2 t/ha
5. **King of bitters/Rice bitters/Kalmegh**: *Andrographis paniculata*: Acanthaceae: Origin: India
   - ☆ Economic part: Whole herb
   - ☆ Uses: To treat snake bites, acute jaundice
   - ☆ Alkaloids:
     - ✦ Major alkaloids in leaves: Andrographolide
     - ✦ Major alkaloids in roots: Andrographidin A, B, C, D, E and F
   - ☆ Kalmegh is propagation: Seeds or cuttings
6. **Safed Musli**: *Chlorophytum borivilianum*: Liliaceae Origin: India
   - ☆ Saponin is the chief medicinal compound present in the roots
   - ☆ Uses: Aphrodisiac, helpful in curing impotency, diabetes, as alternative to viagra
   - ☆ Propagation: Root cuttings
   - ☆ Yield: 2000 kg of fleshy roots/ha
7. **Guggul/Indian Bdellium Tree**: *Commiphora wightii*: Burseraceae: Origin: Africa and Asia
   - ☆ Woody perennial spiny shrub

   - ☆ Economic part: Gum resin
   - ☆ Uses: Treatment of arthritis and obesity
   - ☆ Commercially cultivated in Rajasthan and parts of Gujarat
   - ☆ Active principle: Z and E gugglusterones (Anti-inflammatory, reduction of cholesterol content in blood, hypoglycaemic properties)
   - ☆ Propagation: Semi-wood stem cuttings
   - ☆ Annual pruning is nessary practice
   - ☆ **Variety**: GAU:- Marusudha
   - ☆ Enhancement of gum flow: Application of Ethephon @ 40 ppm
   - ☆ Tapping is done for extraction of gum
   - ☆ Average yield: 200-500 g/tree/season
8. **Henbene/Black henbene:** *Hyocyanmus niger*: Solanaceae Origin: Europe
   - ☆ Long day plant
   - ☆ Economic part: Leaves
   - ☆ Uses: Treatment of asthma, whooping cough and intestinal disorder
   - ☆ Average total alkaloids: 0.05%
   - ☆ Major alkaloids content: Hyoscyamine
   - ☆ Egyptian henbene: *H. muticus* (source of Tropane alkaloids)
   - ☆ **Varieties**:
     - ✦ CIMAP: Aela
     - ✦ CIMAP: Aekla
     - ✦ CIMAP: IC-66:Popular variety due to short duration
   - ☆ Seed rate: 3 kg/ha
   - ☆ Average yield: 2500 kg of dried leaves/ha
9. **Medicinal Yam:** *Dioscorea floribunda:* Dioscoreaceae Origin: Central America
   - ☆ Economic part: Tubers
   - ☆ Diosgenin is the active ingredient for oral contraceptive pills
   - ☆ *Dioscorea floribunda, Diocorea composita* (3%) widely grown for Diosgenin production in India
   - ☆ Diosgenin content in tubers: 2-7%
   - ☆ **Varieties**: Arka Upkar, FB(c)-1
   - ☆ Propagation: Tuber pieces
   - ☆ Average yield: 50-60 tonnes/ha
10. **Foxglove:** *Digitalis lanata*: Scrophulariaceae: Origin: Europe
    - ☆ Economic part: Leaves

- ☆ *Digoxin: Used for heart diseases/life saving medicine*
- ☆ *Two important species:*
  - ✦ *D. lanata* : 1-1.4% glycosides
  - ✦ *D. purpurea* : 0.2-0.4% glycosides
- ☆ *It contains 3 lanatosides A, B, C*
- ☆ *Propagated by seeds (8 kg/ha)*
- ☆ *Yield: Average dried leaves: 2-5.5 tonnes/ha*

11. **Pyrethrum:** *Chrysanthemum cinerariaefolim*: Asteraceae: Origin: Mexico
    - ☆ *Prefers cool and dry climate*
    - ☆ *Pyrethrin is the synthetic insecticide derived from its flowers*
    - ☆ *Kenya is the largest producer in the world*
    - ☆ *Economic part: Flowers*
    - ☆ *Average pyrethrin content in South Indian hills: 1.19%*
    - ☆ *Highest pyrethrin content found in achenes (93%)*
    - ☆ **Variety**: *C-793 is a high pyrethrin variety*
    - ☆ *Propagation: Seeds*
    - ☆ *Maturity index: 3-4 rows of disc florets opened*
    - ☆ *Average yield in South India: 180-400 kg/ha*
    - ☆ *Economic life of plant in South Indian hills: 3-4years*
12. **Opium:** *Papaver somniferum:* Papaveraceae: Origin: Eastern Europe
    - ☆ *Prefers subtropical and temperate climate*
    - ☆ *Uses: Painkiller*
    - ☆ *Opium and codeine are used for analgesia and hypnotic effects*
    - ☆ *Heroine is a semi-synthetic derivative of morphine*
    - ☆ *Fruit type: Capsule*
    - ☆ **Lancing:** *Latex obtained from the matured capsules (40 alkaloids)*
    - ☆ *Lancing done at 15-25 days after fall of petals*
    - ☆ *Total alkaloids contain 9-14% morphine content*
    - ☆ **Varieties**: *Chetak, Jawahar Aphim 16, Ranghatak, Talia, Kirtiman, Swetha, Shyama and Vivek*
      - ✦ *Sanchita: High morphine content in straw*
      - ✦ *Sujatha: Opium free poppy for the production of oil and seed*
      - ✦ *Shubhra: High morphine content*
      - ✦ *Talia and Dholia are local races of Opium*
    - ☆ *Propagation: Seeds (Broadcasting-7-8 kg/ha, Line sowing-4-5 kg/ha)*
    - ☆ *Raw opium yield: 50-60 kg/ha*

13. **Sarpagandha:** *Rauvolfia serpentina*: Apocynaceae: Origin: India
    - ☆ Tuberous soft taproot system
    - ☆ Economic part: Dried root (Total alkaloids: 55 alkaloids)
    - ☆ Uses: Controlling blood pressure
    - ☆ Major alkaloids:
      - ✦ Ajmalicine, Serpentine, Reserpine: Uses- Hypertension, sedative, tranquilising agent
    - ☆ Total alkaloid content:1.4-3%
    - ☆ Average total alkaloid content: Root bark: 2.4% Wood:0.40% and Fibrous root: 2.52%
    - ☆ Propagation: Seeds (6 kg/ha), root cuttings, stem cuttings
    - ☆ Yield: 1.5-2 tonnes of dried roots/ha
14. **Senna:** *Cassia angustifolia*: Fabaceae: Origin: South Africa
    - ☆ It is a leguminous crop but lack of nodule formation
    - ☆ India is the leading producer, exporter in the world
    - ☆ Senna growing districts in Tamil Nadu: Tirunelveli, Rammanathapuram, Madurai and Tuticorin
    - ☆ Economic parts: Leaves and Pods (contains Sennosides A, B, C, D)
    - ☆ Sennosides is used for laxative and purgative purpose
      - ✦ Indian senna (*Cassia angustifolia*) contains 1-5.3% of Sennosides
      - ✦ Alexandrian senna (*Cassia acutifolia*): 4-4.5% of Sennosides
    - ☆ **Variety**: TNAU: KKM-1
    - ☆ Seed rate: 5 kg/ha
    - ☆ Sowing time of Tamil Nadu: February-March (Tirunelveli tracts) and July-November
    - ☆ **Average yield:**
      - ✦ **Irrigated condition**: Dry leaves 1500 kg/ha and Pods 700 kg/ha
      - ✦ **Rainfed condition**: Dry leaves 1000 kg/ha and Pods 400 kg/ha
15. **Pipali/Long pepper:** *Piper longum*: Pieraceae: Origin: Western Ghats of India
    - ☆ Dioecious plant
    - ☆ Commercially grown in homestead and backyard of home
    - ☆ Economic part: Unripe female spikes (*i.e.* Catkins)
    - ☆ Uses: Stimulent, appetizer, tonic
    - ☆ The spikes of this plant contains alkaloids piperine (4-5%)
    - ☆ The roots contain alkaloids piper
    - ☆ Inflorescence type: Spike
    - ☆ Propagation: Root
    - ☆ Variety:

16. **Rye Ergot:**
- ☆ Is a plant disease that is caused by the fungus *Claviceps purpurea*, forms a blackish or brown coloured body
- ☆ Ergot develops on rye spikes- Alkaloids obtained from these affected spikes
- ☆ Alkaloids are used in obstetrics making child birth easy and stoppage of bleeding after the child birth
- ☆ Seed rate: 70-80 kg/ha
- ☆ Sowing time:
  - ✦ September to October in Kashmir Valley
  - ✦ Southern Hills: November
- ☆ Collection of ergot *Sclerotia*: 8-10 weeks after inoculation or 15 days before ripening of rye grains

17. **Indian liquorice/Mulhati:** *Glycyrrhiza glabra*: Fabaceae: Origin: India
- ☆ Grown in undulated lands, riverbed areas
- ☆ Economic part: Roots-sweet substance is glycyrrhizin (50 times sweeter than sugar)
- ☆ Uses: Chronic viral hepatitis, taste modulator, anti-inflammatory, treatment of peptic ulcers
- ☆ Glycyrrhizin is high in older roots
- ☆ Yellow colour of roots is due to isoliqril
- ☆ Propagation: Semi-wood underground stem cuttings
- ☆ **Variety**: Haryana Mulhati-1
- ☆ Seed rate: 300 kg of stem cuttings/ha

18. **Deadly Nightshade/Belladonna:** *Atropa belladonna*: Solanaceae: 2n=72 (Hexaploid)
Origin: Europe
- ☆ Temperate cool season plant
- ☆ Source of tropane alkaloids: 0.13 to 0.7 %
- ☆ Tropane alkaloids: Hyoscine, Hyoscyamine and Atropine- Anticholinergic
- ☆ Uses: Leaves are widely used for the manufacture of tinctures, extract, plasters
- ☆ Treatment of gout, rheumatism Parkinson's disease
  - ✦ Indian belladonna: *Atropa acuminata*- Western Himalayas-Yellow flowers
  - ✦ European belladonna: *Atropa belladonna*- Italy, Yugoslavia- Purple flowers
- ☆ Propagation: Seeds (seed rate @ 1 kg/ha)
- ☆ Yield: 200-400 kg of dried leaves/ha

19. **Medicinal *Solanum*:** *Solanum khasianum:* Solanaceae: Origin: India
- ☆ Steroid bearing perennial bush
- ☆ Economic part: Seed

- ☆ Uses: Contraceptives, corticosteroids and sexhormones
- ☆ Highest solasodine content species: *Solanum incanum* (1.8-2.0%)
- ☆ Berries and pulp have rich source of solasodine
- ☆ Berries-Solasodine (Synthesis of steroidal hormones): 1-1.75%
- ☆ Total solasodine content in berries: 2.5-3%
- ☆ **Varieties**:
  - ✦ Arka Sanjeevini
  - ✦ Arka Mahima: Tetraploid variety
  - ✦ RRL-SL-6 (Spineless mutant)
  - ✦ RRL-20-2
- ☆ Seed rate: 1.25 kg/ha
- ☆ Average dry berries yield: 6-8 tonnes of berries/ha

20. **Psyllium/Isabgol**: *Plantago ovata*: Plantaginaceae: 2n=8: Origin: Persia
- ☆ Stemless annual herb
- ☆ Prefers cool and dry weather (Winter crop is grown in India)
- ☆ Economic part: Seed and husk
- ☆ Used for anti-diarrhoea drug, due to property of absorbing and retaining water (40-90%)
- ☆ In India commonly grown in Gujarat and Rajasthan
- ☆ Gujarat is the leading producer in India
- ☆ Husk (Odourless and tasteless) yields a colloidal mucilage consisting of xylose, arabinose and galacturonic acid
- ☆ Type of flowers: Protogynous
- ☆ Type of fruit: Capsule
- ☆ Inflorescence type: Spikes
- ☆ Propagation: Seed (4-6 kg/ha)
- ☆ **Varieties:**
  - ✦ GAU: Gujarat Isagol-1 and Gujarat Isabgol-2
  - ✦ CIMAP: Niharika
- ☆ Maturity stage: Spike turns brownish
- ☆ Husk : seed ratio is 25:75
- ☆ Average yield: 1 t/ha
- ☆ Downy mildew (*Peronospora plantaginia*) is th... ...iation

21. **Periwinkle**: *Cathranthus roseus*: Apocynaceae: 2n...
- ☆ Perennial ornamental herb fo...
- ☆ Blooms throughout the y...

- ☆ Used as a trap crop for root knot nematode (RKN)
- ☆ Major alkaloids present in roots:
  - ✦ Raubasin (Ajmalicine) and Serpentine- Anti-fibrillic, hypertensive (high blood pressure)
- ☆ Major alkaloids present in leaves (VLB alkaloids: 0.003-0.004%):
  - ✦ Vinblastine and vincristine (Constituent of patented cancer drugs, curing blood caner)
- ☆ Vincristine is present in all parts of the plant but maximum in roots (0.75-1.20%) then leaf (0.6-0.65%)
- ☆ Vincristine sulphate is being marketed under the trade name ONCOVIN which is used against acute leukaemia and Vinblastine sulphate as VELBE to cure Hodgkin's disease
- ☆ Type of fruit: Cylindrical follicle (Black seeds)
- ☆ Propagation: Seeds
  - ✦ Direct sowing crop: 2-3 kg/ha
  - ✦ Transplanting crop: 500 g/ha
- ☆ **Three variants**: *alba*: white flowers *roseus*: pink rose flowers *ocillata:* rose purple spot in the centre
- ☆ ***Varieties:***
  - ✦ *CIMAP: Nirmal- Resistant to wilt and dieback*
  - ✦ *CIMAP: Dhawal*
- ☆ ***Yield***

Economic parts	Rainfed condition (t/ha)	Irrigated condition (t/ha)
Roots	0.75	1.5
Stems	1.0	1.5
Leaves	2	3

1. MEDICINAL PLANTS

S.No	Medicinal Plants	Part Used	Variety	Alkaloids	Uses
1.	Aloe Vera	Leaves	-	Aloin	Laxative Purpose
2.	Asgand (Aswagandha) Indian Ginseng	Roots	Jawahar Asgandh-20	Withanine Somniferine	Aphrodisiac property Immuno-modulator Anti-stress
3.	Medicinal Yam	Tubers	Arka Upkar, FB(c)-1	Diosgenin	Production of Contraceptive Pills
4.	Fox-Glove	Leaves	-	Digoxin	Heart Disease
5.	Opium	Capsule (Latex)	Telia, Dholia	Codeine	Painkiller
6.	Dill or Sowa	Seeds	-	Carvone	Improve digestion, Control vomiting, Carminative property
7.	Guggul (Kiluvai)	Oleogum Resin	-	Z and E-Gugglusteroids	Anti-inflammatory Hypoglycaemic
8.	Henbene	Leaves	-	Hyoscyamine	Anti-asthma Anti-cholicgenic
9.	Isabgol	Husk, seed	Gujarat Isabgol-1,2	Mucilage	Anti-diarrhoea Laxative
10.	Khasi-Kateri	Fruits	Arka Sanjeevani	Solasodine	Production of Contraceptive Pills
11.	Liquorice	Roots	Haryana lathi 1	Gl hizin	Anti-inflammatory Spasmolytic activity
12.	Per		nal, val		Tranquilizer ancer neoplastic

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3.	Medicinal Yam	Tubers	Arka Upkar, FB(c)-1	Diosgenin	Production of Contraceptive Pills
4.	Fox-Glove	Leaves	-	Digoxin	Heart Disease
5.	Opium	Capsule (Latex)	Telia, Dholia	Codeine	Painkiller
6.	Dill or Sowa	Seeds	-	Carvone	Improve digestion, Control vomiting, Carminative property
7.	Guggul (Kiluvai)	Oleogum Resin	-	Z and E-Guggluteroids	Anti-inflammatory Hypoglycaemic
8.	Henbene	Leaves	-	Hyoscyamine	Anti-asthma Anti-cholicgenic
9.	Isabgol	Husk, seed	Gujarat Isabgol-1,2	Mucilage	Anti-diarrhoea Laxative
10.	Khasi-Kateri	Fruits	Arka Sanjeevani	Solasodine	Production of Contraceptive Pills
11.	Liquorice	Roots	Haryana Mulathi 1	Glycyrrhizin	Anti-inflammatory Spasmolytic activity
12.	Periwinkle	Roots and Leaves	Nirmal, Dhawal	Vinblastine Vincristine Ajmalcine	Tranquilizer Anticancer Anti-neoplastic

13.	Pipali	Unripe Fruit (Female Spike)	Vishwam	Piperine	Improve appetite Laxative
14.	Sarpagandha	Roots	RS-1	Serpentine Ajmalicine Reserpine	Anti-Blood pressure
15.	Senna	Leaves and Pods	KKM-1	Sennosides (A, B,C)	Laxative and Constipation
16.	Kalmegh (King of Bitterness)	Whole Plants	-	-	Jaundice
17.	Glory Lily (State Flower of Tamil Nadu)	Seeds	-	Colchicine	Anti-Gout (Joint Pain)
18.	Cinchona	Bark	-	Quinine	Treatment of Malaria
19.	Datura	Whole plant		Hyoscine, Tropane	Preanasthetic surgery
20.	Abroma	Root bark			intra-uterine diseases and other gynaecological disorders

2. MEDICINAL PLANTS

Common name	Botanical Name	Features
Sweet flag (Vasumbu)	*Acorus calamus* Araceae	Aquatic perennial herb, Propagation: Rhizome Economic part: Rhizome, Bitter principle: Acorin Used: Expectorant action and Remedy for asthma
Adhatoda	*Adhathoda vasica* Acanthaceae	Economic part: Leaves and roots, Alkaloids: Vasicine Uses: Asthma, Chronic bronchitis, cough
Indian Penny Wort (Vallarai)	*Centella asiatica* Umbelliferae	Economic part: Leaves Volatile: Vellarine, Fresh leaves contain a glucoside asiaticoside and Asiatic acid Uses: Blood purifier, Memory enhancer, treatment of leprosy **Varieties**: Majjaposhak and Kayakirti (CIMAP)
Ipecac	*Cephaelis ipecacuanha* Rubiaceae	Economic part: Whole plant Alkaloids: Emetine Uses: Treatment of amoebiasis
Medicinal *Coleus*	*Coleus forskholii* Lamiaceae	Economic part: Tuberous roots, Alkaloids: Forskholin (Syn. Coleonol) Uses: Hypertension and Eye disorder
Datura (Umattai)	*Datura stamonium* Solanaceae	Economic part: Leaves and Fruits Alkaloids: Stramonium (Hyoscyamine and Scopolamine) Uses: Pre-anaesthetic in surgery and child birth
Glory lily, gloriosa lily or lily flower (State flower of TN)	*Gloriosa superba* Liliaceae	Economic parts: Seeds and tubers Alkaloids: Colchicine, 0.7 to 0.9 seeds 0.15 to 0.3 tubers Uses: Colchicine is used in the treatment of `Gout', a common disorder Propagation: V' shaped rhizomes
Madhunasini	*Gymnema sylvestris* Asclepiadaceae	Economic parts: Leaves, Uses: anti-diabetic property Alkaloids: Gymnemic acid
Indian Saraparilla (Nannari)	*Hemidesmus indicus* Asclepiadaceae	Economic part: Roots Uses: Tonic and blood purifier

Leucas (Thumbai)	*Leucas aspera* Labiate	Economic part: Leaves Uses: Anti-pyretic, Chronic rheumatism
Killanelli	*Phyllanthus niruri* Euphorbiaceae	Economic part: Whole plant, Uses: Hepatitis B and Jaundice Alkaloids: Phyllanthin and hypophyllanthin **Varieties**: CIMAP: Navyakrit
Thippli	*Piper longum* Piperaceae	Economic part: Dried unripe fruits Uses: Tonic, Cough and cold
Tuthuvalai	*Solanum trilobatum* Solanaceae	Economic part: Berries and flowers Uses: Chronic bronchitis
Tylophora (Asthamakodi)	*Tylophora asthmatica* Asclepiadaceae	Economic part: Whole plant Alkaloids: Tylophorin Uses: Dysentery, Expectorant
Brahmi	*Bacopa monnieri* Scrophulariacae	Economic part: Whole plant Alkaloids : Brahmine and herpestine Uses: Enhancing memory and vitality (Celestrial drugs) **Varieties**: Pragyashakti and Subodhak (CIMAP)
Cinchona	*C. officinalis* Rubiaceae	Economic part :Bark Uses: Anti-malarial drugs Alkaloids : Quinine
Insulin plant	*Cheilocostus speciosus* Costaceae	Alkaloids: Diosgenin Uses: sex hormones and steroidal drugs for family planning and health programmes all over the world
Cowhedge	*Mucuna pruriens* Fabaceae	Economic part: Seeds Alkaloids: Mucunine and mucunadine Uses: Treatment of elephantiasis Aphrodisiac, Nervine tonic
Sweet worm wood	*Artemisia annua* Asteraceae Origin: China	Alkaloids: Artemisinin (0.05-0.17%) Uses: Anti-malarial drug **Varieties**: Asha, Jeevanraksha, Suraksha (CIMAP)
bane	*Hyoscyamus niger* Solanaceae	Tropane alkaloids (Hyoscine)

B. AROMATIC CROPS

1. **Ambrette or Muskdana**, *Abelmoschus moschatus*: Malvaceae: 2n=72: Origin: India
   - ☆ Economic part: Seeds
   - ☆ Uses: Cosmetics, scents and perfume
   - ☆ Musk odour of seeds is due to mixture of farnesol and ambrettolide (0.12 and 0.03%)
   - ☆ Seed rate: 1.5 kg/ha
   - ☆ Major economic product: Concrete and Seed oil
2. **Celery**: *Apium graveolens*: Apiaceae: 2n=22: Origin: Mediterranean region
   - ☆ Economic part: seed
   - ☆ Uses: Appetizer, carminative property
   - ☆ Seed oil contains selinene, d-limonene
   - ☆ Type of pollination: Cross (Protandrous flowers)
   - ☆ **Variety**: RRL-85-1
   - ☆ Seed rate: 1 kg/ha
   - ☆ Seed shattering is a major problem in seed production
3. **Chamomile**: *Matricaria chamomilla*: Asteraceae: Origin: Central Europe
   - ☆ Economic part: Flowers
   - ☆ Flower oil: Blue oil- used for manufacturing of pain reliving palms, antibacterial and antifungal
   - ☆ **Varieties**: Soraskar-60, CIMAP: Vallary
   - ☆ Seed rate: 1 kg/ha
   - ☆ Fresh flower yield: 6 t/ha
   - ☆ Blue oil colour is due to chamzulene content
   - ☆ Oil yield: 200-250 litres per hectare
4. **Davana**: *Artemisia pallens*, Asteraceae: 2n=16: Origin: India
   - ☆ Economic part: Leaves and flower tops
   - ☆ Uses: Floral decoration, bouquets and cosmetics
   - ☆ Flower type: Capitulum
   - ☆ Oil content rich in Davanone- Used in perfumery industry
   - ☆ Odour compounds: Devanafurans and iso-davanone
   - ☆ Commercially grown in Theni District (Aundipatti taluk) of Tamil Nadu
   - ☆ Propagation: Seed (1.5 kg/ha)
   - ☆ 1g contains 1600 seeds
   - ☆ Average fresh herbage yield: 15 t/ha

☆ *Related species: Artemisia annua:* Oil content: 0.3-0.4%

5. **French Jasmine**: *Jasminum grandiflorum*: 2n=32: Origin: India
   - ☆ *Economic part: Flowers*
   - ☆ *India is 2nd largest producer of concrete after Egypt*
   - ☆ *Propagation: Stem cuttings*
   - ☆ *Major product: Concrete*
   - ☆ *340-400 flowers yields 1kg of concrete*
6. **Indian Basil**: *Ocimum basilicum*: Lamiaceae Origin: India
   - ☆ *Long day plant*
   - ☆ *Economic part: Whole plant*
   - ☆ *Oil contains methyl chavicol 70-80%*
   - ☆ *Sweet basil contains eugenol and linalool*
   - ☆ *Seed rate 250 g/ha*
   - ☆ *Average yield: 15-20 kg/ha*
   - ☆ *Fresh herbage oil yield: 0.4-0.5%*
   - ☆ *Oil yield: 66-70 kg/ha*
7. **Java citronella**: *Cymbopogon winterianus* (High citronellal) Poaceae: 2n=20: Origin: Srilanka
   - ☆ *Large perennial, stemless aromatic crop*
   - ☆ *Moisture loving plant*
   - ☆ *Shade sensitive crop*
   - ☆ *Short day plant*
   - ☆ *Economic part: Leaves*
   - ☆ *Uses: Mosquito repellent and deodorants*

   Varieties: **CIMAP**: *Manjusha, Mandakini, Jorlab-2, Java Sel.2, Manjari, Jorhat-C2, Bio-13, Medni, Jal Pallavi*
   - ☆ *Propagation: Rooted slips*
   - ☆ *Yield:40-50 tonnes/ha*
   - ☆ *Oil: 250-300 kg of oil/ha*

Lemon grass: *Cymbopogon spp.*: Poaceae: Origin: India

☆ *Lemon has good soil binding nature, so it is used for soil and conservation purpose*

☆ *Economic part: Leaves and shoots stemless perennial sedge, hardy drought tolerant crop*

☆ *Uses: Cosmetics, flavours and perfumes*

Citral is the starting material for the preparation of Ionone

'β-Ione' used in the manufacture of synthetic Vitamin-A

☆ **Varieties:** Trishna, Jamrosa
☆ *Harvesting stage: Flower opening stage*
☆ *Herbage yield: 15-20 t/ha*
☆ *Oil yield: 50-50 kg/year*

10. **Vettiver/Khus-khus**: *Vetiveria zizanioides*: Poaceae: 2n=20: Origin: India
☆ *Xerophytic grass*
☆ *Commonly grown flood inundualted and soil eroded lands*
☆ *Good soil binding property*
☆ *Economic part: Leaves and roots*
☆ **Varieties**: Nilambore, Sugandha
☆ *Propagation: Rooted slips*
☆ *Average yield: 5-7 tonnes/ha*
☆ *Oil yield: 15-16 kg/ha (Oil content: Veteverol)*

11. **Screw pine/Kewada**: *Pandanus fasicularius:* Pandanaceae, Origin: Madagascar
☆ *Aerial roots is characteristic feature of plant*
☆ *Commercially grown in Odisha and Kerala*
☆ *Tolerant to drought and floods*
☆ *Economic part: Flower (Male Spadix)- Oil content: 0.03%*
☆ *Propagation: Crown suckers*
☆ *Flower period: May-June*
☆ *Major products: Attar oil*

12. **Mints:** ***Mentha* spp.**

Japanese mint/corn mint/Field mint: *M. arvensis* var. *piperascens*: Lamiaceae: Origin: Mediterranean region
☆ *Prefers cooler climate*
☆ *Shallow rooted plant*
☆ *Long day plant*
☆ *High menthol content species*
☆ *All mint inflorescence type: Spikes*
Never set seeds due to interspecific hybrid origin
It is the raw material for the manufacture of menthol
Propagation: Suckers or stolons
Planting material requirement: 500-600 kg suckers/ha
Varieties: *Gomti, Kalka, Himalaya, Kosi, Kushal, Saksham, Sambhav*

☆ Shiwalik is most popular variety in India
☆ Crop maturity determined by Clevenger's apparatus
☆ Average yield: 30 t/ha
☆ Steam distillation is good for extraction of mentha oil
☆ Oil yield:150 kg of oil/year
☆ Average oil content: 0.5%

13. **Peppermint:** *M. piperita*
☆ Requires temperate and subtropical climate
☆ Peppermint contains Menthol (25-40%) and menthone (30-40%)
☆ Planting time: End of December-March
☆ Best month for higher herbage yield: 2nd week of February
☆ **Varieties**: Kukrail, CIMAP: Madhuras, CIMAP: Indus
☆ Lowest oil yield: 80 kg/ha (High menthol content)
☆ Average oil content: 0.25%

14. **Common/spear mint/garden mint**: *M. spicata*
☆ Contains 70-80% menthone
☆ Oil rich in carvone content (caraway like odour)
☆ **CIMAP Varieties**: Released two strain of Spear mint: 1. MSS-1 and 2. MSS-5, Supriya, Ganga
☆ 20 tonnes of spearmint herbage yields 17 kg of oil
☆ Average oil content: 0.57%
☆ Oil recovery: 0.11-0.14%

15. **Scotch spearmint** (*Mentha cardiaca*) oil contains 65% of carvone

16. **Bergamot mint/Lemon /orange mint:** *M. citrata*
☆ Prefers temperate climate
☆ Tolerant to frost
☆ **Variety**: Kiran is mutant variety of bergamot mint released from CIMAP
☆ Bergamot mint oil is rich in linalool and linalyl acetate (Odour like lavender)
☆ Increasing the herbage yield, application of GA_3 @ 200 ppm is recommended
☆ Oil contains 40 – 60% linalool and 9 – 27% linalylacetate
☆ Oil recovery: 0.2 – 0.6%
☆ Oil yield: 75 – 150 kg/ha

17. **Ocimum**: *Ocimum spp.* Lamiaceae: Origin: India
☆ Rich in natural source of camphor: *Ocimum kilimandscharicum* and *O. canum*

☆ Substitute to eugenol yielding tree crops: *Ocimum gratissimum* (Clocimum) (Eugenol- 75%)
☆ Ocimum oil recovery: 0.5%
☆ Ocimum oil has antifungal, antibacterial and insecticidal properties
☆ Flower is protandrous
☆ Highly cross pollinated crop is due to protandry
☆ Mode of pollination: Honeybees

Important species:

✦ *O. santum:* Sacred by Hindus
✦ *O. gratissimum* mostly cultivated species in North India
✦ *O. santum:* 60-75% eugenol; Essential oil content: 0.5-1.0%
✦ *O. gratissimum:* 70-80% eugenol; Essential oil content: 0.5-1.5%
✦ French basil/Roman Basil: *O.basilicum:* Volatile oil- d-linalool (55%) and methyl chavicol (75%)

☆ Propagation: Seeds 200-250 g/ha
☆ **Varieties of French basil**: RRL-011, Kusumohak, Vikarsudha
☆ Herbage Yield: 20-30 t/ha

atchouli: *Pogostemon patchouli* 2n=30: Lamiaceae: Origin: South East Asia
Prefers hot and humid condition
Short day plant
Used as catch crop
Used as intercrop in coconut and rubber plantation
Natural condition never flower
ndonesia is the largest producer of Patchouli Oil
opagation: Terminal shoot cuttings
ghest oil content: Top 3 leaves
ior constituent is patchoulol (30-40% in patchouli oil)
houli oil is used as a base material in perfumery industry (Fixative Properties)
ontent in leaves: 2-6%
covery: 3-3.5%
val of moisture in oil: Sodium sulphate
best: Nematodes

ium: *Pelargonium graveolens:* Geraniaceae: 2n=88: Origin: South Africa
eranium is widely used for in scenting of soaps & for the isolation of Rhodinal which t of most high grade perfumes
it is bei[illegible] Kodaikanal Hills of Tamil Nadu

☆ **2 types of geranium**:
✦ Algerian or Tunisian (Slender with Dark Pink flowers)
✦ Bourbon or Reunion (Sturdy with Light Pink Flowers): Suitable for wet conditions
☆ Propagation: Long terminal cuttings
☆ **Varieties**: Hemanti, Bipuli and Kunti
☆ Horticultural Research Station, Kodaikanal, TNAU: KKL-1
☆ Egyptian type: Drought hardy, tolerant to high temperature and wilt
☆ Cuttings is done at 3-4 times/year
☆ Maximum oil content: Leaf blade
☆ Geranium oil content: 0.8-0.15%
☆ Oil yield: 15 kg/ha
☆ Leaf yield: 15-18 t/ha

20. **Scented Rose**: *Rosa damascena*: Rosaceae: Origin: India
☆ Major products: Rose water and attar
☆ Economic part: Petals
☆ Rose oil obtained from papillae of epidermal cell
☆ **Varieties:**
✦ Noorjehan (Indo-Gangetic plains): Popular variety in India
✦ Jawala: Subtropical hills
✦ Himroz: Temperate region
☆ Propagation: Stem cuttings
☆ Pruning time: December

21. **Eucalyptus:** *Eucalyptus spp.*: Myrtaceae: Origin: Australia
☆ Economic part: Leaves
☆ Term eucalyptus oil denotes 3 distinct group of essential oils
✦ Medicinal type: Blue gum (*Eucalyptus globules*): High cineol content
✦ Perfumery type: *Eucalyptus citriodora:* High cintronellal and phellandrene
✦ Phellandrene rich type: *Eucalyptus citriodora*
☆ Lemongrass or citron scented gum:
✦ *Eucalyptus citriodora:* Most commonly grown in hill stations of South India
☆ Propagation: Seeds
☆ Eucalyptus oil contains hydroxyl citronellal- used for manufacture of high grade perfumes
☆ Coppicing is practiced in every 4th year in *Eucalyptus*
☆ Pollarding is a method of harvesting

- ☆ Leaf harvest time: March-May
- ☆ Steam distillation is the best method for leaf oil extraction

22. **Lavender**: *Lavendula* spp: Lamiaceae: 2n = 42 or 48
- ☆ France is the largest supplier of lavender oil in the world
- ☆ Lavender oil is obtained from 2 Species (i.e. True and spike lavender)
  - ✦ True Lavender: *Lavendula angustifolia*
  - ✦ Spike Lavender: *Lavendula latifolia*
  - ✦ Hybrid Lavender or Lavindin: *Lavendula hybrida*
- ☆ Lavender generally prefers dry & cool climate except *Lavendula stoechas*
- ☆ **Varieties**: CIMAP/B-15 (Sher-e-Kashmir), Karlovo
- ☆ Lavender oil contains Linalool and Linalyl acetate
- ☆ Lavender oil is commonly used in perfumery industry
- ☆ Propagation: Seeds or cuttings
- ☆ Lavender oil contains 50-53% of ester
- ☆ Average herbage yield: 2000 kg/ha

23. **Sandalwood:** *Santalum album:* Family: Santalaceae Origin: India
- ☆ Evergreen tree
- ☆ Heartwood that constitutes the central part of the tree: for its fragrance
- ☆ It is obligatory root parasite
- ☆ Centered heart wood is most valuable portion in sandalwood
- ☆ India is source of world famous sandalwood oil- used for perfumery industry
- ☆ Propagation: Seeds
- ☆ Heart wood formation is good in trees of 30-60 years
- Average heartwood yield: 19-50 kg/tree
- Sandalwood oil contains α and β-santalols (90-93% of oil)
- Seed germination is a major problem

er economic aromatic plants:

Kapur/Karpur/Karpuram: *Cinaamomum camphora* (Camphor oil content: 50%)

osemary: *Rosemarinus officinalis* chief constituent being comphene (11.2%) and 1, 8-neole (19.2%)

AROMATIC PLANTS

S.No	Aromatic Plants	Part Used	Oil Content	Uses
1.	Ambrette/Muskdana	Seeds	Farnesol and Ambreetolide	Musk odour used in incense sticks, Pannesala, Perfumery, Cosmetics and Scents
2.	Celery	Seeds	Selinene, limonene	Seasoning, Flavouring Sauces, Purees
3.	Chamomile	Flowers	Blue Oil	Pain Relieving balm
4.	Davana	Leaves	Hydrocarbons	Delicate fragrance for floral decoration, bouquets
5.	Indian Basil	Leaves	Methyl Chavicol Eugenol and Linalool	Flavouring foods
6.	Java Citronella	Leaves	Citronellal	Mosquito repellents Deodorants, scented soaps
7.	Kewada	Flowers	Luplin	Kewada water
8.	Lemon Grass	Leaves and shoots	Citral	Starting material for Ionones
9.	Mint	Leaves	Menthol, Carvone	Scenting Supari
10.	Palmarosa Grass	Leaves and shoots	Geraniol	Soaps, Perfumery industry
11.	Patchouli	Leaves	Patchouliol	Fixative Property
12.	Rose Geranium	Leaves and Flowers	Rhodinol	Perfume industry
13.	Vettiver	Roots	Citronellal	Carminative Property
14.	Indian Basil	Leaves and	Methyl Chavicol	Flavouring foods
15.	Rosemary		Cineol	Anti-cancer, anti-oxidant
16.	Oil bearing			Rose oil, Ruha Gulab

Chapter – 9 : Post Harvest Technology

A. Post Harvest Technology

- ★ **Post harvest losses in various fruits and vegetables**
- ★ **Biochemical changes during ripening of fruits and vegetables**
- ★ **Major post harvest diseases**
- ★ **Classification of fruits based on climacteric pattern**
- ★ **Maturity index of important horticultural crops**
- ★ **Post harvest practices**
  - ♣ Curing
  - ♣ Waxing
  - ♣ Packaging techniques
  - ♣ Degreening
  - ♣ Precooling and its methods

Post Harvest Technology for Fruit Crops

- ★ **Storage techniques for fruits**
  - ♣ Low cost storage technology
  - ♣ High cost storage technology

Post Harvest Technology for Vegetable Crops

- ♣ Vegetables classification based on respiration
- ♣ Pre-harvest practices
- ♣ Curing techniques

Post Harvest Technology of Flower Crops

- ★ **Storage techniques for flowers**
  - ♣ Wet storage
  - ♣ Dry storage
  - ♣ Refrigerated storage for flowers
- ★ **Post harvest treatments**
  - ♣ Pulsing/loading
  - ♣ Vase solutions
  - ♣ Impregnation
  - ♣ Bud opening solutions
  - ♣ Holding solution
  - ♣ Conditioning/Hardening

★ Total post harvest losses in fruits and vegetables: 20-40%

★ Post-harvest losses in India are estimated to range from 14-36% in fruits and 10-25% in vegetables

Post harvest losses in various fruits and vegetables:

Fruit/Vegetables	Post harvest losses (%)
Mango	17-37
Banana	12-14
Papaya	90-100
Citrus (orange)	8-31
Apple	10-25
Grapes	23-30
Cauliflower	10-15
Onion	15-30
Potato	15-20
Tomato	10-20

Biochemical changes during ripening of fruits and vegetables:

- ★ Respiration: enzymatic process, influences the storage life of produces
- ★ Temperature quotient (Q10): ratio of the rate of reaction at temperature, every 10°C rise of temperature (5 to 25°C) range respiration rate increases 2 to 2.5 times
- ★ Transpiration: fresh produces control temperature by water evaporation
- ★ Metabolic activities generally increase 2 to 3 fold for every 10°C rise in temperature
- ★ Respiration causes loss of sugars and other flavour compounds and produces heat known as 'vital heat'
- ★ Usually organic acids decline during ripening as they are respired or converted to sugars
- ★ During senescence, the level of free amino acids increases reflecting a breakdown of enzymes and decreased metabolic activity (Exception: Banana and pineapple where acidity increases during ripening)
- ★ Phenolics such as tannins are [illegible] compounds, resulting in a [illegible] astringency in the ripe ba[illegible]
- ★ Sensitive [illegible]
- ★ Crit[illegible]
- ★ [illegible]

Major post harvest diseases:

★ More acidic fruit tissue is generally attacked by fungi while vegetables having pH above 4.5 are more commonly attacked by bacteria

- ✦ Bacterial soft rot of potato: *Erwinia spp.*
- ✦ Dry rot: *Fusarium spp.*,
- ✦ Black rot of sweet potato: *Ceratocystis fimbriata*
- ✦ Water soft rot of carrot: *Sclerotinia sclerotiorum*
- ✦ Soft rot of leafy vegetables: *Erwinia carotovora*
- ✦ Dry rot: *Fusarium* spp.

Classification of fruits based on climacteric pattern:

★ Climacteric fruits: defined as the fruit showing a large increase in carbon dioxide and ethylene production rates coincided with ripening, non-climacteric fruits show no change in the CO_2 and ethylene production rates during ripening

- Increase the production of both respiration and ethylene during ripening process
- Fruits are harvested at unripe stage and allowed for ripening during storage after harvest
- e.g. Apple, pear, peach, plum, persimmon, apricot, avocado, tomato, watermelon, kiwi, fig, mango, banana, papaya, guava, blueberry, cherimoya, ber, melons, sapota, passion fruit

★ ***Non-climacteric fruit:***

- ✦ Steady decline in respiration without ethylene production during ripening
- ✦ Fruits harvested only at ripe stage
- ✦ e.g. Citrus fruits, Grapes, Grape fruit, Cucumber, Pineapple, Strawberry, Tree tomato, Sweet Cherry, Carambola, Cherries, Litchi, Loquat, Olive, Pomegranate, *Rin* and *Nor* mutants of Tomato

★ **Maturity index of important horticultural crops:**

Horticultural Crops	Maturity Index
Mango	Tapka
Banana	Finger Filling/Angularity
Jackfruit and Watermelon	Tapping
Muskmelon	Netting or Full slip stage
Onion and Garlic	Neck fall (50%)
Citrus	Juice content (50%)
Avacado	Oil content
Apple	T stage
Pineapple	Flattening of eyes

Post harvest practices:

★ Washing: chlorine used for disinfectants to wash fruits and vegetables

★ **Curing**: Hardening of epidermal layer (outer tissue) of bulb and root crops by exposing to high RH and temperature *e.g.* Onion, Garlic, Sweet Potato, Tapioca

★ **Degreening:**

- ✦ Degradation of chlorophyll in mango, banana, tomato, citrus fruits by artificial application of ethylene
- ✦ Best degreening temperature @ 27°C, 85-90% RH
- ✦ Most widely used growth regulator for degreening: Ethrel

★ Artificial ripening: Ethylene or Ethrel (Mango, banana)

★ Synthetic ripening: Calcium carbide produces acetylene gas (CaC_2) (Used earlier, now banned)

★ Ethylene absorber or scrubber: $KMnO_4$

★ Ethylene ripening champer: fruits exposed to low level of ethylene 100-150 ppm an air tight champer for 24 hours to ripen (temperature 16-25°C with RH 90-95%)

★ Banana ripening champer: 100 ppm, 24 hours, temperature 16-18°C with RH 90-95%

★ Mango ripening champer: 100 ppm, 24 hours, temperature 20-22°C with RH 90-95%

★ Ethylene inhibitors: Silverthiosulphate (STS), Silver nitrate ($AgNo_3$), 1-MCP

Irradiation

♣ Uses a for energy ionizing radiation

♣ Exposing food either or packaged for gamma rays for a specific time

♣ The effect dose measured by kilograys (kGy)

♣ Low dose of irradiation: <1 kGy (disrupts the cellular activity to inhibit the sprouting of tubers, bulbs and roots)

♣ Medium dose (1-10 kGy) kills fu… …est

Waxing:

★ **Waxing**: Application of fu… …ce… …along with edible wax for increase shelf-life …

- ✦ **Storage wax:** …
- ✦ **Pack-out w** …
- ✦ **High-shi** … …mmediately

★ **Trade name of e** …

- ✦ Frutox…
- ✦ Wax
- ✦ W…
- ✦ T…

- Semper-fresh
- Fruit and vegetable kleen
- Decco Luter

★ Chlorine concentrations of 200ppm (free chlorine) are generally used in hydrocoolers

Pre-cooling:

★ Rapid removal of field heat from harvested vegetables and fruits e.g. Okra, Garden Pea

Precooling and its methods:

★ Precooling refers to the rapid removal of field heat before shipment or storage

★ Generally, precooling is completed within 24hrs, but for highly perishable fruits, it should be done within 2-3 hours

★ For tropical and subtropical fruits precooling at 10-13°C

★ Berries, peaches, plums, grapes, early apples, mature pears are precooled at 5°C

★ Using cold air: room cooling, forced-air cooling

★ Most common precooling technique is room cooling

★ In hydrocooling, water is the heat transfer medium

★ Hydrocooling (cold water) is a rapid cooling method

★ Hydro-cooling uses water as the cooling medium and is commonly used for root, stem and flower-type vegetables, melons and some tree fruits

★ Contact-icing: direct contact with ice

★ Evaporation of water from produce: Evaporative cooling, vacuum cooling

★ Hydrovac cooling: combination of vacuum and hydro cooling

★ Forced-air cooling method is commonly used on crops such as grapes, berries stem vegetables, many leafy vegetables and fruit-type (vegetables tomatoes, melons) and cut flowers

★ Forced-air cooling is the most widely adaptable and commonly used for many fruits

Package icing used for root and stem vegetables, broccoli and brussels sprouts

Vacuum cooling method is used primarily for cooling leafy vegetables, celery, cauliflower

Hydro-vacuum cooling process is called hydrovac cooling

Vacuum and water spray vacuum-cooling are usually reserved for leafy vegetables

Conduction and convection are the two main heat-transfer mechanisms used for cooling produce

ing techniques:

dividual seal shrink wrapping technique which may be considered as the modified osphere packaging (MAP) for an individual fruit

kaging of whole or fresh cut produce in a plastic films

ue package should be used for potatoes for delaying greening

★ Rate of respiration and metabolism doubles for every 10°C rise in temperature

★ Covering the fruits after harvest with any material in order to improve its post harvest life is known as wrapping e.g. Tissue paper, waxed paper, plinfilm, Cellophane paper, aluminium foils and alkathene paper

★ Waxing of fruits helps in reducing the moisture loss, improving the appearance of fruits and minimising the incidence of storage diseases

★ Vacuum packaging (VP) referred to the removal of all air within the package without deliberate replacement with another gas e.g. Guava

★ Vacuum packaging is a simple method than other method

★ Seal packaging: Apple, pear, kiwifruit and citrus and pomegranate

★ Polyethylene and polypropylene bags of 100 gauge are normally used for mushroom packaging

★ Polyvinylchloride (PVC): Used primarily for over wrapping

★ Polypropylene (PP) and polyethylene (PE): Used for bags are the films most widely used for packaging minimally processed products

★ Environment friendly packaging material containers:
  - Sal leaves (*Shorea robusta*) and Arecanut leaf sheath (*Areca catechu*)

★ **Palletization:** Loading and unloading are done manually in India. Due to low unit load, there is a tendency to throw, drop or mishandle the package, damaging the commodity. This loss can be considerably reduced by using pallet system

Post Harvest Technology of Fruit Crops

Storage techniques for fruits:

★ Normally storage temperature for temperate fruits: 0-1.1°C

★ Relative humidity inside the cold room should preferably be maintained high (90 - 95 %)

★ For perishable commodities, the RH is kept in the range of 90 to 95 %

Low cost storage technology:

★ Zero Energy Cool Chamber (ZECC) (working under the principle of evaporative cooling) was developed by S.K. Roy and S.R. Khurdiya, IARI

★ In India, potato traditionally stored in sand brick kiln soil

★ Traditional method of storing potatoes: Clamps

★ Night Ventilation (Air cool storage): Widely used in high hill regions

★ Cellars storage is used for storing onions and during the winter

★ In Sudan, onions are st

High cost storage

- Con
- M

★ Refrigerants commonly used in refrigerated storage: Freon, ammonia and methyl chloride
★ Freon is most popular, odourless, non toxic

Controlled atmospheric storage (CAS storage):

★ Low O_2 and high CO_2 stored at gas tight containers at optimum storage temperature e.g. mango, pear and tomato
★ Generally above 1% of CO_2 and below 8% of O_2 used in CA storage
★ CA storage was first suggested by W.R. Philips, Canada
★ Most fruits and vegetables tolerate O_2 levels down to 1-5 % and CO_2 levels up to 5-10%
★ Apple: CA storage:10% of CO_2 and 11% O_2 with a temperature of 4° C

Modified Atmospheric Storage (MAS):

★ Recently in MAS method maintaining the RH at 90 to 95% is recommended for the storage of green vegetables and other root and tuber vegetables to prolong the storage life
★ Most commonly used Oxygen absorbers in MAS: Ferrous oxide (FeO): Iron powder
★ Most commonly used CO_2 absorbers in MAS: Hydrated lime, activated charcoal, magnesium oxide
★ Most commonly used ethylene absorbers in MAS: Potassium permanganate absorbed on celite, vermiculite, silica gel or alumina pellets

Hypobaric storage (HBS):

★ A modification in the CA storage is the use of sub-atmospheric pressure to store the horticultural produce
★ Hypobaric storage involves the cold storage of horticultural produce under partial vacuum
★ Most widely used for cut flowers

Recommended storage temperature, relative humidity, and storage life of fresh fruits for commercial storage

Fruit	Temperature (°C)	Relative humidity (%)	Approx. storage life
Apple	-1-4	85-90	4-8 months
Apricot	-0.5-0.0	85-90	1-2 weeks
Grape	-1.1	90-95	3-6 weeks
Guava	7.2-10.0	90	2-3 weeks
Kiwifruit	-0.5-0	90-95	3-5 months
Lemon	8.9-10.0	85-90	1-6 months
Litchi	2.1	90-95	3-5 weeks
Mango	11.7-12.8	85-90	2-3 weeks
Olive	7.2-10.0	85-90	4-6 weeks

Papaya	7.2	85-90	1-2 weeks
Peach	0.0-3.0	85-90	2-4 weeks
Pomegranate	0.0	90	2-4 weeks
Mandarin	0.0-4.2	85-90	2-4 weeks
Strawberry	0.0	90-95	5-7 days

Post-harvest technology for vegetable crops

Vegetables classification based on respiration:

1. Vegetables with low respiratory activity (< 40 mg CO_2/Kg/hr) → potato, onion and cucumber
2. Vegetables with moderate respiratory activity (40-80 mg CO_2/Kg/hr) → pepper, carrot and tomato
3. Vegetables with high respiratory activity (80 - 120 mg CO_2/Kg/hr) → peas and radish
4. Vegetables with very high respiratory activity (> 120 mg CO_2/Kg/hr) → Green onion, melons, cauliflower, okra, parsley and mushrooms

★ Susceptible to chilling injury: Tomato, brinjal, pepper, cucumber, snap bean, summer squash, pumpkin and watermelon
★ Non-chilling sensitive commodities: Broccoli and peas
★ High respiration vegetables: Asparagus, broccoli, peas or sweet corn

Pre-harvest practices:

★ Pre-harvest application of maleic hydrazide (MH) reduces sprouting of onions and potatoes during storage
★ In *rabi* and *kharif* onions, application of Maleic hydrazide 1500-2000 ppm after 75-90 days of transplanting reduces sprouting during 4-5 months of storage in ventilated structures
★ Pre-harvest application of 500 ppm maleic hydrazide, 15 days before harvest of the bulbs will prevent the sprouting of the onion bulb in storage and keep the bulbs healthy for about 6-7 months
★ Pre-harvest application of growth promoters such as N-benzyl adenine (10 -20ppm) prolongs shelf-life of leafy vegetables
★ Mango: Topsin-M or Bavistin at 0.1% at three times [illegible] days interval controls anthracnose and stem end rot

Curing techniques:

★ Curing is done in onion, garlic, potato, swe[illegible]
★ Maximum safe temperature for onion c[illegible]

- ★ Temperature for artificial curing of onion: 40°C for 16 hrs
- ★ Most effective temperature for potato curing: 20°C @ 85% RH
- ★ Most effective temperature for sweet potato curing: 29°C
- ★ Most vegetables require 2-5 minutes for blanching @ 90-95°C
- ★ Potato stored in cold storage @ 2-4°C
- ★ Most commercially used blanching techniques in canning industry: Hot water blanching
- ★ Brine floatation technique is commercially used in peas and beans
- ★ Most used package desiccants for partial dehydration of vegetables: Calcium oxide or fumed silicas
- ★ Ethylene absorbers: Purafil (Alkaline $KMnO_4$), brominated activated carbon

Post Harvest Technology of Flower Crops

- ★ **Non-climacteric flower:** Delphinium (Highly sensitive to ethylene)
- ★ **Climacteric flower:** Carnation
- ★ Storage is not recommended: Dahlia, *Calendula*, *Zinnia*
- ★ Anthurium, Vandal, Cattleya and Bird of Paradise are sensitive to chilling injury

Particulars	Flowers
Highly sensitive to ethylene	Alstromeria, carnation, freesia, gypsophila, lily, narcissus, orchids, antirrhinum
Insensitive to ethylene	Anthurium, gerbera, rose
Highly sensitive to chilling injury	Anthurium, bird of paradise
Less sensitive to chilling injury	Chrysanthemum, gerbera, china aster
Highly suceptible to grey mould	Gladiolus, bird of paradise
Highly toxic to fluorides	Gladiolus, freesia, gerbera, chrysanthemum and rose
Sensitive to geotropic bending	Freesia, snapdragon and gladiolus

★ Flowers sensitive to geotropic bending must be transported in upright position

Optimum Stages of Harvesting for Important Flowers

Flower name	Stage of harvest
Rose	1-2 petals beginning to unfold
Gladiolus	1-5 florets show colour
Lilium	Coloured buds
Carnation	Paint brush stage
Narcissus	Goose neck stage
Anthurium	Spadix almost fully developed
Chrysanthemum - Standard	When outer florets fully expanded
Gerbera	Flowers open but outer 2 rows show shedding of pollens (fully mature)
Alstroemaria	4-5 florets open
Dendrobium	Fully open flowers
China Aster	Fully open flower

Storage techniques for flowers:

- ★ Storage temperature for tropical flowers: 10-15°C e.g. Anthurium, cattleya and poinsettia
- ★ Storage temperature for sub-tropical flowers: 2-8°C e.g. Gladiolus, strelitzia and anemone
- ★ CO_2 levels higher than 4% cause injury to many flowers whereas O_2 levels lower than 0.4% produce anaerobic conditions
- ★ Low pressure storage or Hypobaric storage was 1st described Burg and Burg (1966)
- ★ Hypobaric or Low pressure storage (LPS) is the storage at low atmosphere pressure under refrigerated conditions, continuous ventilation and high RH
- ★ Refrigerated storage is the most widely used method for the storage of cut flowers
- ★ Refrigerated storage is of two types: (i) wet [illegible] dry storage
- ★ **Wet storage:**
  - ✦ Flower [illegible] servative solution
  - ✦ The [illegible] the dry storage
  - ✦ [illegible] day to day
- ★ D[illegible]

Refrigerated Storage for Flowers

Storage	Crop	Storage temperature	Maximum storage period
Dry	Carnation	0 to 1°C	16-24 weeks
	Chrysanthemum	1°C	3 weeks
	Gerbera	2°C	2 days
	Gladiolus	4°C	2-3 weeks
	Rose	0.5 to 2°C	2 weeks
Wet	Anthurium	13°C	2-4 weeks
	Carnation	4°C	4 weeks
	Dendrobium	5 to 7°C	10-14 days
	Gerbera	4°C	3-4 weeks
	Gladiolus	0.5 to 1.6°C	10 days
	Tuberose	7 to 10°C	3-5 days

Post harvest treatments:

- ★ The term 'cut flower' is used to define the flower which is cut along with portion of the stem
- ★ The demand for cut blooms in the global market is increasing at 10 -15% per year
- ★ The RH of air during precooling and shipment of cut flowers should be 95-98%
- ★ The water for fresh cut flowers should have a pH: 3.5-4.5
- ★ The optimum amount of total dissolved solids in water for cut flowers should be <200 ppm
- ★ 'Floral preservative' is used for any chemical formulation which is used for extending the vase life of flowers
- ★ Most commonly used sugar in the vase solution: Sucrose
- ★ Floral preservatives have two basic constituents *viz.*, sugar and biocide
- ★ Sucrose is the most widely used sugar in floral preservatives
- ★ Sugar provides an additional food to the cut flower, sucrose level in vase solutions: 0.5 to 2.0%
- ★ Most commonly used acidifying agent in the vase solution: Citric acid
- ★ Acidifying water to low pH: 3.0-3.5
- ★ New promising fresh flower preservatives are amino-oxyacetic acid (AOA)
- ★ Best preservative for cut flowers: Silver thiosulphate (STS)
- ★ Boiling water treatment for base of cut flowers (30 seconds) is followed in dahlia, zinnia and rose
- ★ Burning the base of cut flowers (15 seconds) is followed in *Poinsettia* and Nerium

- ★ 'Pulsing' refers short duration (16-24 hr) pre-shipment or pre-storage treatment
- ★ Bud opening solutions': Immature buds of many flowers can be made to open in chemical solutions
- ★ Bud opening solutions: Lower concentrations of sucrose
- ★ Holding or Vase solutions are meant to hold flowers continuously, till the termination of their vase life
- ★ Presence of sodium ions in vase water is detrimental for roses
- ★ Biocide inhibit the growth of bacteria, fungi and other microorganisms in the vase solution
- ★ Most commonly used biocide in the vase solution: Quinelline salts
- ★ Important biocides used for treating cut flowers:
  - ✦ 8-hydroxy quinoline citrate (8-HQC), 8-hydroxy quinoline sulphate (8-HQS) silver nitrate, aluminium sulphate, citric acid
- ★ IAA rather promotes petal senescence in carnation by enhancing ethylene production
- ★ Gibberellin (GA_3): promotes the bud opening in carnation
- ★ Ethylene (hydrocarbon gas): Induces senescence of many flowers
- ★ Among greenhouse rose cultivars longer vase life: Vivaldi, Red Success, Samoura, Ravel and Konfetti
- ★ In cut roses cv. Raktagandha, 25-100 Krad of gamma irradiation prolonged the vase life
- ★ Prolonging the lives of cut roses cv. Priyadarshini 50 Krad of gamma rays
- ★ Important post harvest disease is due high humidity and temperature: Grey mould (*Botrytis cinerea*)

Important terms used in Post-harvest treatments for flowers

- ♣ Light requiring flowers: chrysanthemum, alstroemeria, marguerite daisy (darkness leads to yellowing)
- ♣ Air embolism: Air embolism occurs when small bubbles of air (emboli) are drawn into the stem at the time of cutting. e.g. Rose

Water quality:

- ▪ Sodium sensitive/toxic to flower crops: carnation, rose
- ▪ Fluoride (F) is very toxic to gerbera, gladiolus, roses and freesia
- ▪ Ethylene sensitive flowers: Carnation, gypsophila
- ▪ Ethylene (100 ppb): expose to cut flowers can
- ▪ Reduction of ethylene effects: STS, 1-MCP
- ▪ Growth tropisms: cut flowers to environm

  1. Geotropism: (bending away
  2. Phototropism: (bending to

result in quality loss

gladiolus,

Pulsing/loading:

- Pulsing is done by standing the freshly harvested cut flowers in solution for a short period e.g. Gladiolus
- Preshipment treatment
- Short term treatment
- Pulsing given to the cut flowers before packing and transportation of flowers
- Time for pulsing: 12-24 hrs, under a light intensity of 1000 lux and 20 to 27°C
- Pulsing treatment promote opening and increase the shelf life of flower
- Sugar and other chemicals used for pulsing
- Sucrose (2 to 20%) is most commonly used for pulsing (Osmo-regulation) e.g. gladiolus, tuberose, hybrid statice, lisianthus
- Pulsed with silver thiosulphate (STS) e.g. ethylene-sensitive flowers e.g. Carnation, delphinium and gypsophila
- Pulsed with GA: prevent leaf yellowing e.g. Alstroemeria

Bud opening solutions:

- ★ Bud-cut flowers must be opened in bud-opening solutions before they are sold to the consumer
- ★ These solutions contain a germicide and sugar
- ★ It is a procedure for harvesting flowers at storage earlier than normally coincided by cutting stage
- ★ Bud opening method is identical to pulsing, longer duration and low concentration of sugar
- ★ 8-HQC, Silver thiosulphate (STS), KCl, Al_2SO_4, 4% sucrose are used for bud opening

Vase solutions:

- ★ Holding solutions used in the vases to keep flowers for extending their vase life
- ★ Solutions: Sugar + Germicide + Growth regulator + Organic acid + Ethylene inhibitor
- ★ Commonly used: Sucrose + Citric acid + Quinoline salt (8-HQC, 8-HQS)

Holding solution:

- ★ Use of preservative in the form of tablets
- ★ Prepared by mixture of chemicals (Sugar, germicides, salt, growth regulator)

Conditioning/Hardening:

- ★ Flowers are kept standing loosely in a big container, so that air can circulate around the stems
- ★ Purpose: Restore the turgidity of cut flower from water stress during storage and transportation
- ★ Water + Germicides + Citric acid @ 500 ppm pH: 4.5-5.0

Impregnation:

- ★ Ends of the cut flower stems are impregnated for short time with chemicals
- ★ Prevents blockage of xylem vessel in the stem by microbial growth and stem decay
- ★ Commonly used chemicals for impregnation: $AgNO_3$, $NiCl_2$, $CoCl_2$ @ 10-15 minutes

Post harvest research centers in India:

- ★ Central Food Technological Research Institute (CFTRI), Mysore, Karnataka
- ★ Central Post Harvest Engineering and Technology (CIPHET), Ludhiana, Punjab
- ★ Fruit Preservation and Canning Institute (FPCI) is located at Lucknow, UP
- ★ Regional Research Laboratory (R.R.L.) Jammu
- ★ Bhabha Atomic Research Centre (BARC), Bombay
- ★ CSIR Laboratory, Palampur, DFRL, Mysore
- ★ All India Coordinated Research Project on Post harvest Technology (AICRP) of horticultural crops was started by the ICAR in August 1978

B. Processing Technology of Horticultural Crops

- ★ **Methods of preservation**
  - o Preservation by high temperature
    - ▪ Pasteurization
    - ▪ Sterilization
  - o Preservation by low temperature
  - o Preservation by chemical preservatives
  - o Preservation by fermentation
  - o Preservation by carbonation
  - o Preservation by irradiation
  - o Preservation by antibiotics
- ★ ***CANNING***
  - ♣ Canning of fruits and vegetables:
  - ♣ Peeling
  - ♣ Blanching
  - ♣ Vegetable cultivars for canning
  - ♣ Sulphuring
  - ♣ Syruping
  - ♣ Brining
  - ♣ Classification of fruits and vegetables based on pH
  - ♣ Spoilage of canning of foods
- ★ Freezing of fruits and vegetables
- ★ Preservation by dehydration
- ★ Vegetable cultivars for drying
- ★ Preparation of various products from horticultural crops:
  - ♣ Jam
  - ♣ Jelly
  - ♣ Classification of fruits based on their pectin and acid content
  - ♣ Marmalade
  - ♣ Other products
  - ♣ Vinegar
  - ♣ Pickles

- ★ Beverages
  - ♣ Fruit beverages
  - ♣ Unfermented beverages
  - ♣ Important fruit beverages FPO specifications
  - ♣ Fermented beverages
- ★ Processing of tomato
- ★ Major products
- ★ Papain
- ★ Points to ponder
- ★ FOOD SPOILAGE
  - ♣ Browning reactions
  - ♣ Type of spoilage in fruits and vegetables
  - ♣ Spoilage due to mechanical damage
  - ♣ Useful bacteria
  - ♣ Vinegar bacteria
  - ♣ Lactic acid bacteria
  - ♣ Yeast
  - ♣ Moulds
  - ♣ Natural toxins
- ★ Statutory provisions for quality control in India
- ★ Central Food Laboratories

1. Preservation by hig… …servation
   - ★ Asepsis: Absen…
   - ★ Filtration: Re…
   - i. Pasteurizatio…
     - ★ Heatin…
     - ★ Past…
     - ★ Fl…

★ Bottle or holding pasteurization: Most commonly used for the preservation of fruit juices at home

★ RTS and Nectar are pasteurized at about 85°C for 25 to 30 minutes

★ Overflow method is most suitable for grape juice

★ Overflow method of juice is heated rapidly about 2.5°C higher than the pasteurization temperature

★ Thermal death time (TDT) is defined as the time required at a given temperature to kill a stated number of organisms under specific conditions

★ Mould spores are destroyed by heating at 79°C for 5 to 10 minutes

★ Yeast and acid tolerant bacteria are killed at 66°C

★ Pectic enzymes in juice can be destroyed by heating the juice at about 85°C for 4 min or 88°C for 1 min

ii. Sterilization:

★ Hot pack or hot fill is generally used in home for jam preparation

★ Heat sterilization is the most effective process of food preservation

★ Aseptic canning/martin aseptic canning/ultra high temperature (UHT) sterilization: 149°C in 1-2 sec

★ Fruit and tomato products should be heated at 100°C for 30 min. to kill the spore forming bacteria

★ Sterilization temperature for spore forming bacteria: 110°C, 30-90minutes

★ Spore forming bacteria: *Bacillus subtilis* and *Bacillus mesentericus*

Pasteurization	Sterilization
Partial destruction of microbes	Complete destruction of microbes
Temperature <100°C	Temperature >100°C
Commonly used for fruit juices	Commonly used for canning of vegetables

2. Preservation by low temperature:

★ **Low temperature preservation methods:**

✦ Cellar storage(15°C): e.g. Root crops, potatoes, onions and apples are most suitable

✦ Refrigeration or chilling method: 0 to 5°C

✦ Freezing method: -18°C to -40°C

★ Best way preserving pure fruit juice: Freezing

★ Most harmless method of preservation is freezing

★ Frozen foods should always be kept at below -5°C

3. Preservation by chemical preservatives:

★ Preservative means any substance which is capable of inhibiting, retarding or arresting the process of fermentation, acidification or other decomposition of food

★ **Class I Preservative**: Sugar ,Salt, Spices

★ **Class II Preservative**: Sodium benzoate, Potassium metabisulphite

★ Any substances added to food by the process of curing is known as smoking

★ Salt act as a preservative: 15-25%

★ Fruit syrup, jam, jelly, marmalade, preserve, candy, crystallised fruit and glazed fruit are preserved by sugar

★ Sugar act as a preservative: 62-65%

★ Alcohol acts as a preservative in wines: 14%

★ Acetic acid (vinegar), citric acid (lime juice) and lactic acid are commonly used for preservation

★ Citric acid is added to many fruit squashes, jams and jellies to increase the acidity and prevent mould growth

★ Vinegar contains 5% acetic acid

★ For pickles, chutneys, sauces and ketchups-vinegar is recommended

★ About 2% acetic acid prevents spoilage of many products

★ Turmeric, pepper and asafoetida have bacteriostatic effect

★ Permitted preservatives in all countries: Sulphur dioxide and Benzoic acid

Products	Sulphur dioxide (SO_2)	Benzoic acid
Read to serve (RTS) and nectar	100 ppm	100 ppm
Squash, crush and cordial	350 ppm	600 ppm
Fruit juice	700 ppm	-
More effective against	Bacteria, moulds and inhibits enzymes	Yeast
Usage	Cannot be used in coloured juices	Mostly used in coloured products
	Act as antioxidant	Antiba… incr… C…

★ Common stab…

★ Recomm…

★ *pH level of majority fruit juices: 3.5 to 4.0*

★ *General pH in citrus squashes and cordials: 2.5 to 3.5*

★ *Recommended preservative for coloured products of tomato, phalsa, jamun, pomegranate, plum, watermelon, strawberry and coloured grapes:* Sodium Benzoate

★ *pH range for the growth:*

- ✦ *Moulds → 1.5-8.5*
- ✦ *Yeasts → 2.5-8.0*
- ✦ *Bacteria → 4.0-7.5*

4. Preservation by fermentation:

★ Wine, beers, vinegar, fermented drinks and fermented pickle are preserved by fermentation process

★ *Production of vinegar:* Acetic acid fermentation

★ *Production of wine:* Alcoholic fermentation

★ *Production of pickles and saurkraut* (Cabbage fermented product): Lactic acid fermentation

5. Preservation by carbonation:

★ *Generally, fruit juice beverages are bottled with* CO_2 @ 1-8 g/Litre

★ *Keeping quality of carbonated fruit beverages is enhanced by adding about* 0.005% sodium benzoate

★ *Required* CO_2 *for complete inhibition of microbial activity:* 14.6g/litre

6. Preservation by irradiation:

★ *Irradiation is also known as cold sterilization i.e* food is free of microorganisms without high temperature treatment

★ *Irradiation or Cold Sterilization: To increase shelf life of bulbs, tuber crops and delay ripening in fruits*

★ *Ultra-Filtration or Cold Process: To removal of microbes from juice*

★ *The WHO and IAEA have recommended that radiation dose up to 1Mrad is not hazardous*

★ *Radiation sensitiveness of different micro-organisms:*

- ✦ *Humans:* 10^2 *to* 10^3 *rad*
- ✦ *Insects:* 10^3 *to* 10^6 *rad*
- ✦ *Microorganisms:* 10^3-10^7 *rad*

★ *Sprouting of potatoes, onions carrots are inhibited by* 10^3 *to* 10^4 *rad*

★ *Sterilizing dose for bacterial endospores is* 3.0×10^6

★ *Sterilizing dose for yeasts and fungi is* 5.0×10^4

7. Preservation by antibiotics:

★ *Nisin* is an antibiotic produced by *Streptococcus lactis* commonly found in milk, curd, cheese and other fermented milk products

★ Nisin suppresses the growth of gas, spore forming and toxin producing *Clostridium botulinum*

★ Nisin is commonly used for canning of mushrooms, tomatoes and milk products.

★ *Pimaricin* an antifungal antibiotic is commonly used for treating fruits and fruit juices

★ *Subtilin* producing bacteria: *Bacillus subtilis*: Used in preservation of asparagus, corn and peas

★ Subtilin is most effective against gram positive bacteria and spore forming organisms

★ Recommended *subtilin* for canned peas and tomatoes is 10 and 20ppm respectively

CANNING

8.1. Canning of fruits and vegetables:

★ Definition: Process of sealing food stuffs hermetically in containers and sterilizing them by heat for long storage

★ Father of canning: Nicolas Appert

★ Canning is also known as 'appertizing'

★ Canning of fruits introduced in USA on commercial scale by William Underwood (1817)

★ 1g of soil contains 10^{12} spores of microorganisms

8.2. Peeling:

★ Hand peeling: Mango and papaya (irregular fruits)

★ Steam peeling: Potato, tomato, free stone and clingstone peaches

★ Mechanical peeling: Apple, peach, pineapple, cherries and root crops (Carrot, turnip and potato)

★ Lye peeling: Peach, apricot, sweet orange, mandarin and vegetables (Carrot and sweet potato)

★ Lye peeling is done by 1-2% NaOH (Boiling caustic soda)

★ Flame peeling: Garlic and onion

★ The specific term used for peeling in vegetables: Peas→Shelled, Carrot→Scraped and Beans→Snipped

8.3. Blanching:

★ Blanching is also known as scalding, parboiling or pre-cooking

★ **Blanching**: Inactivates natural enzymes and microbes in fruits and

★ **Blanching**: Act as a pre-treatment (Boilin
Cabbage, Beans

★ Blanchi

★ Ave

Glaust

★ Most common vegetable utilized for blanching: green beans, carrots, okra, turnip and cabbage
★ Chemical added for prevention of chlorophyll conversion into pheophytin during blanching: Sodium bicarbonate
★ **Browning**: Many cut fruits and vegetables have tendency to turn brown when exposure to air is due to polyphenol oxidase (PPO) activity

8.3.1. Vegetable cultivars for canning

Vegetable	Cultivars
Tomato	Pearl Harbour, Marglobe, Kullu Valley, Sioux, Italian pear, Red Top, Roma
Pea	Alaska, Perfection, Horsford Marked Garden, Sutton, Abundance, S-537, Advance , Admiral, early perfection, Prince of Wales, Green Giant
Potato	Kufri Jyoti, Kufri Chandramukhi
Okra	EMS-8, Punjab-7, Punjab Padmini, Pusa Sawani, Vaishali Vadhu
Cabbage	Lucknow Local, Drum Head, Infusion of Glory, Pride of India, Golden acre, Giant Snow Ball, Imperial
Bitter gourd	BG-14, C-96
Beans	French bean: Selection No. 572, Contender
	Bush cultivars: Blue Lake
Beet	Wisconsin, New York, Washington and Oregon Detroit Dark Red

8.4. Sulphuring:

★ Exposure of whole fruits, slices or pieces into burning sulphur fumes is done in sulphur box
★ Used to prevent the oxidation and darkening of fruits
★ Timing for exposure in sulphur box: 30-60minutes
★ Sulphur dioxide (SO_2) fumes used: To check moulds
★ Commonly used for fruits
★ Sweating: Keeping dried products in boxes or bins to equalize moisture content

8.5. Syruping:

★ A solution of sugar in water is called as syrup
★ Syruping is done only for fruits
★ Sucrose syrup is used for canning
★ Syruping concentration: 20 to 55°C
★ Syrup should be filled at 79 to 82°C, leaving head space of 0.3 to 0.5cm

8.6. Brining:

★ A solution of salt in water is called as brine
★ Brining is done only for vegetables
★ Brining concentration:1-3%
★ Brining filled at 79 to 82°C, leaving head space of 0.3 to 0.5cm
★ Process of removal of air from cans: Exhausting
★ Time of exhausting varies from 6 to 10 min.
★ During sealing of cans, the temperature should not fall below 74°C
★ Almost all fruits and acid vegetables can be processed at 100°C
★ Fruits and acid vegetables are generally processed in open type cookers, continuous non-agitating cookers and continuous agitating cookers
★ Vegetables processing temperature: 115 to 121°C under a pressure of 0.70 to 1.05kg/cm^2
★ Vegetables (non-acid) are processed under steam pressure in closed resorts known as automatic pressure cookers
★ Acid vegetables: Tomato and rhubarb
★ After processing, the cans are cooled rapidly to 39°C for stopping cooking process and to prevent stack burn

8.6.1. Classification of fruits and vegetables based on pH:

Class	pH	Fruits/vegetables/Products
Low acid/non acid	>5.0	Peas, asparagus, cauliflower, spinach, beet, corn, French bean, lima bean
Medium acid	4.5 to 5.0	Okra, carrot, okra, cabbage, pumpkin, beet, green bean, *soups and sauces*
Acid	3.7 to 4.5	Tomato, mango, banana, pineapple, jack, apple, pear, peach, sweet cherry
High acid	< 3.7	Rhubarb, sauerkraut, citrus juice, pickles and chutney

★ Lacquering is the process of coating the inside of can with lacquer (Golden coloured enamel) which prevents discolouration
★ Acid resistant lacquer or R-enamel or AR cans: Acidic fruits and vegetables
★ Sulphur resistant lacquer or C-enamel or SR cans: Used for vegetables and non-acid foods
★ SR cans used for non acid foods only like pea, corn, lima bean and red kidney bean

Spoilage of canning of foods:

★ Thermophilic bacteria is common at 100°C
★ Flat sour: *Bacillus sp.*: Common in non-acid foods and ve

- ★ Thermophilic acid (TA) spoilage: *Clostridium thermosaccharolyticum*
  - ✦ Swelling due to CO_2 and Hydrogen
  - ✦ Common in low and medium acid foods
- ★ Sulphur stinker: *Clostridium nigrificans*: Common in low acid fruits
- ★ Mesophilic micro-organism spoilage below 38°C

9. Freezing of fruits and vegetables:

- ★ Suitable fruits for freezing: Mango slices or pulp, guava slices, pineapple slices and orange segments
- ★ Suitable vegetables for freezing: Peas, cauliflower, beans and carrot
- ★ Freezing temperature for beans, carrot, peas, cauliflower, guava and orange freezing: -1 to -5°C
- ★ Freezing storage temperature for beans, carrot, peas, cauliflower, guava and orange freezing: -18°C
- ★ Outer portions 1st change form solid ice to liquid water followed by melting of the central portions is known as "thawing"
- ★ Colour retention in stored foods is more in freezing method than canning technique
- ★ Microbial growth is completely suppressed at below -2°C but chemical reactions continue upto -18°C
- ★ **Freezing**: Freezing with cryogenic liquids like liquid N_2 @ -196°C

10. Preservation by dehydration:

Dehydration of fruits and vegetables:

- ★ Drying or dehydration is the most widely used method of preservation
- ★ Dried/concentrated products are called as high sugar high acid foods or high value low volume foods
- ★ Dehydration refers to the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, relative humidity and air flow
- ★ Initial temperature of the dehydrator: 43°C
- ★ Dehydration temperature for vegetables: 60-66°C and for fruits: 66-71°C
- ★ Residual moisture in vegetables should not be more than 6-8% and in fruits 10-20%
- ★ Psychometric relation: Relationship between the moisture content and temperature of air during drying
- ★ Fluidized bed and foam mat drying are mainly used for vegetables
- ★ Rehydration of dried fruits is done at 54-65°C

Vegetable cultivars for drying

Vegetables	Cultivars
Okra	Pusa Sawani
Tomatoes	Pusa Ruby
Peas	Little Marvel, Varanasi Sweet, Duke of Albany, Meera Sweetville
Onion	Pusa White Round, Pusa White Flat, Rapidi, Udaipur 101 and 102, N-53

- ★ Spray drying is suitable for fruit juice concentrates
- ★ Vacuum dehydration is most suitable for low moisture/low sugar fruits like peaches and apricots
- ★ Tunnel and continuous belt driers are most commonly used for dehydrating fruits and vegetables
- ★ Moisture content of intermediate moisture food (IMF): 20-50%

11. Jam:

- ★ **Jam** (68.5% sugar, 0.5-0.6% acidity): Boiling fruit pulp with sufficient sugar which make thick consistency *eg.* Mango, Strawberry
- ★ Jam contains 0.5-0.6% acid and invert sugar should not be more than 40%
- ★ Judging end point of jam by sheet or flake test and temperature test
- ★ End point of jelly: 68-70% TSS @ 105°C
- ★ Crystallization of jam occurs when cane sugar is less than 20%
- ★ To avoid crystallization of jam corn syrup or glucose must be added
- ★ Sticky or gummy jam is due to high TSS
- ★ Sticky or gummy jam can be solved by addition of pectin or citric acid or both
- ★ Premature setting of jam is due to low TSS and high pectin
- ★ Surface graining and shrinkage is due to high evaporation of moisture of jam during storage
- ★ Microbial spoilage (moulds) when jam is exposed to more than 30%RH
- ★ Advisable limit of sulphur dioxide in the form of KMS in jam: 40ppm

12. Jelly:

- ★ **Jelly** (65% sugar, 0.5-0.75% Acidity): Semi-solid product: Boiling clear aromatic solution of pectin containing fruit extract, free from pulp after addition of sugar and acid
  - ✦ Pectin content in jelly: 0.5-1.0%
  - ✦ Acid content in jelly: 0.5-0.75%
  - ✦ Total soluble
- ★ Most important

★ Guava (High pectin content) most suitable for jelly preparation
★ The optimum pH for jelly is 3.2
  ✦ 60°B of jelly pH: 3.0
  ✦ 65°B of jelly pH: 3.2
  ✦ 70°B of jelly pH: 3.4

12.1. Classification of fruits based on their pectin and acid content:

Rich in pectin and acid	Jamun, Grape, Sour guava, lemon, sour orange, sour plum, sour crab apple
Rich in pectin and low acid	Unripe banana & fig, sour cherry, ripe guava, pear, peel of orange and grape fruit
Low in pectin and rich acid	Pineapple, sweet cherry, sour peach, sour apricot
Low in pectin and acid	Pomegranate, Raspberry, ripe apricot, ripe peach

★ Recommended acid for jelly: Citric acid (2g/kg of fruit)
★ Determination of pectin content by alcohol test and jelmeter test
★ Judging end point of jelly by sheet or flake test, drop test and temperature test
★ End point of jelly: 65% TSS @ 105°C
★ Ripe fruits: Protopectin (water insoluble) → Protopectinase → Pectin (water soluble pectinic acid)
★ Overripe fruits: Pectin→ Pectic Methyl Esterase (PME) → Pectic acid (water insoluble)
★ Firm ripe fruits is most suitable for jelly making
★ Firmness of fruits due to calcium pectate
★ Premature gelation is due to excess of pectin
★ Formation of crystals or crystallization of jelly is due to excess sugar
★ The phenomenon of spontaneous exudation of fluid from a gel is called syneresis or weeping jelly
★ Syneresis is due to excess of acid, low sugar, insufficient pectin, premature gelation and fermentation
★ Cloudy or foggy jellies is due to use of immature fruits, over cooking and over cooling
★ Failure to set jelly is due to lack of pectin
★ Tough jelly is due to high pectin content
★ Removal of scum or foam by addition of edible oil

. Marmalade:

★ **Marmalade**: Fruit jelly with addition of its peel e.g. Sweet Orange

★ Browning is common problem in marmalade
★ Browning of marmalade is prevented by addition of KMS (0.09g/kg of marmalade)
★ Cooking temperature for marmalade is 103 to 105°C
★ Cooling temperature for marmalade is 82-88°C
★ End point of marmalade: 65% TSS @ 105°C
★ Sweet orange peel is most commonly used in preparation of marmalade
★ Jelly marmalade: Clarified extract of pectin is used
★ Jam marmalade: Whole pulp is used

Other products:

★ **Preserve**: Mature fruit/vegetable impregnated with heavy sugar syrup till it becomes tender and transparent
★ **Candy**: Mature fruit/vegetable impregnated with cane sugar syrup and subsequently dried free of syrup and dried *eg.* Ginger, Ber, Aonla
★ **Glazed fruit**: Covering of candied fruit/vegetable with a thin transparent coating of sugar for glossy appearance
★ **Crystallized fruits**: candied fruit when covered or coated with crystals of sugar

14. Vinegar:

★ The word vinegar is derived from French "vinaigre" means 'sour wine'
★ Vinegar contains 5% acetic acid and has germicidal and antiseptic properties
★ Vinegar is obtained through alcoholic and acetic acid fermentation
★ Amount of acid in vinegar is expressed as 'grain strength'
★ 1% acetic acid is termed as 10 grain strength
★ Fermentation temperature for vinegar production: 21-27°C
★ Aging or maturation time for vinegar: 4 to 8 months
★ Ideal vinegar should contain only 0.3% sugar
★ Pasteurization of vinegar is done at 77°C for 15 to 20 min.
★ Optimum temperature for the activity of vinegar bacteria: 27-30°C
★ Wine flower, lactic acid bacteria, vinegar flies (*Drosophila cellaris*), vinegar eels are problem in vinegar production
★ Lactic acid bacteria is most common in fermented juice of vinegar
★ Wine flower and lactic acid bacteria can be prevented by addition of 20-25% unpasteurized vinegar
★ Vinegar eels (*Anguillula*) is killed by heating [illegible]°C

Lactic acid fermentation	
Lettucekraut	Lettuce
Saurkraut	Cabbage
Saurruben	Turnip
Tarhana	Vegetables+milk
Sajurasin	Vegetables+rice
Paw Tsay	Mixed vegetables + cabbage + turnips + radish
Kimchi	Mixed vegetables + Chinese cabbage

15. Pickles:

- ★ Preservation of food in common salt or in vinegar is known as "pickling"
- ★ Pickling is the result of fermentation by "lactic acid bacteria"
- ★ Mango pickles ranks 1st followed by cauliflower, onion, turnip and lime pickles in India
- ★ Boiled product: Chutney
- ★ Major export chutney in India: Mango chutney
- ★ Lactic acid bacteria are most active at 30°C
- ★ Lactic acid bacteria grow in 8-10% of salt solution
- ★ Growth of majority of spoilage organisms is inhibited by 15% of salt
- ★ Advisable to place vegetables in 10% salt solution for vigorous lactic acid bacteria
- ★ Preservation by salt (15% or above) method of preservation is mostly used in vegetables
- ★ Pickles preserved by oil: Mango, cauliflower
- ★ Finished pickle should not be less than 2% acetic acid
- ★ Recommended vinegar strength for vegetables or fruits pickle: 10% strength
- ★ Softness and slipperiness is very common problem in pickle
- ★ Softness and slipperiness is due to use of weak brine
- ★ Cloudiness of pickle is due to use of inferior quality of vinegar eg. Onion
- ★ Blackening is due to iron in the brine solution
- ★ Scum formation is due to growth of wild yeast
- ★ Shrivelling of pickles is due to vegetables placed in very strong salt or sugar or vinegar e.g. Cucumber, gherkin

16. Fruit beverages:

Unfermented beverages	Fermented beverages
Natural sweetened juices	Wine
Ready to serve (RTS)	Champaigne (Sparkling wine cv. Pinot Noir)
Nectar	Port (Sweet fortified red wine from Portugal)
Cordial	Sherry (Spanish wine)
Squash	Tokay (Fortified wine from Hungary)
Crush	Muscat (Muscat grapes)
Syrup	Perry (Pear)
Fruit juice concentrate	Orange wine (Orange juice)
Fruit juice powder	Berry wine (Strawberry, black berry)
Barley waters	Nira (Palm)
Carbonated beverages	Cider (Apple, bael), Feni (Cashew apple)

16.1. Unfermented beverages:

- ★ Synthetic drinks contain only water (88%) and total carbohydrates (12%)
- ★ Synthetic drinks provides 48Kcal
- ★ Tannin-gelatin method is most widely used for clarifying fruit juices
- ★ Most important filter aids are supercel, kieselguhr and spanish clay
- ★ Fining agent: Gelatin, albumen and casein
- ★ Gelatin is mostly used for apple and cashew apple juices
- ★ Commonly used pectic enzymes for destroying the pectin in fruit juices: Pectinol and Filtragol
- ★ Fruit juices, RTS and nectars are preserved by pasteurization
- ★ **Cordial**: Sparkling clear, sweetened fruit juice from pulp
- ★ Cordial is most suitable for blending with wines
- ★ Squashes, crushes and cordials are preserved by only by chemicals
- ★ General head space for bottled fruit juice beverages 1.5 to 2.5cm
- ★ To stop the enzymatic action in fruit juices it heated by 77oC for 30m
- ★ All juices are sweetened by
- ★ Recommended fortifi
  250-500mg/litre
- ★ Recomme

★ Citric acid commonly used in all types of beverages
★ Bitterness of mandarin orange juice is due to limonin
★ Mango, orange and pineapple are used for making squash commercially
★ Phalsa, aonla, jamun, pomegranate, grape, lemon orange and ginger are used for the preparation of syrup
★ Synthetic syrup contains 70-75% of sugar syrup
★ Barley water is prepared from citrus fruits such as lime, lemon, grapefruit and orange
★ Mostly widely used citrus fruits in barley water: Lime and Lemon
★ In carbonated beverages 0.05% of sodium benzoate must be added

16.1.2. Important fruit beverages FPO specification:

Products	Fruit Juice (%)	TSS (%)	Acidity (%)	SO_2 (ppm)
Not Diluted Before Serving				
Unsweetened juices	100	Natural	-	
Sweetened juices	85	10	--	
RTS	10	10	0.3	-
Nectar	20	15		-
Cordial (Lime and Lemon)	25	30	1.5	350
Barley water	25	30	1.0	Barley starch (0.25%)
Fruit juice concentrate	-	32	-	-
Diluted Before Serving				
Squash	25	40-50	1	350 ppm SO_2 or 600 ppm sodium benzoate
Crush		55		-
Syrup		65	1.3-1.5	-

16.2. Fermented beverages:

★ Development of biochemical principles of fermentation was originated by Lavoisier (1789) in France
★ Wine is a beverage resulting from the fermentation of grape juice by yeasts

★ Wines prepared from Fruits: Perry-Pears, Berry- Strawberry, Blackberry, Elderberry, Nira-Palmyarah, Feni-Cashew, Cider-Apple, Champaigne-Grapes
★ Alcohol content of wine ranges from 7 to 20 %

Types of wine	Alcohol (%)
Light wine	7-9
Medium wine	9-16
Strong wine	16-21
Sparkling wine	CO_2
Still wine	No. CO_2
Fortified wine	Addition of alcohol in the form of brandy
Red wine	From coloured grapes (skin intact)
White wine	From white/green grapes (skin removed)
Dry wines	Very little/no sugar is detected
Sweet wines	High sugar content can be detected

★ Suitable fining agent for wine is bentonite
★ Acid content in grapes for wine: 0.6 to 0.8%
★ Optimum temperature for fermentation of grape wine is 22-28°C
★ Aging or maturation time for wing: 6-8 months
★ Common yeast used in wine: *Saccharomyces cerevisiae* var. *ellipsoideus* (20 ml/kg of grapes)
★ Common yeast used in cider: *Saccharomyces carlbergensis*
★ Generally wines are pasteurized at 82-88°C for 1-2 minutes
★ Wine made from pears is known as *perry*
★ *Feni* is a fermented wine made from cashew apple in Goa
★ In USA, Apple cider: non-clarified apple juice
★ In India, Apple cider: fermented apple juice
★ Cider apples contain higher percentage of sugar 12.5% (*i.e.* Fructose)
★ Bael, jamun, phalsa and aonla are most widely used for preparation of cider
★ Common preservative used in cider: SO_2 @ 100 ppm or KMS (0.22g/kg)
★ Cider is mostly prepared from fermentation of special grades of
★ For cider preparation of apple should have 0.1-0.3%
★ *Port* is a fortified sweet red wine made originally in Po
★ *Champaigne* is a sparkling wine made from France

★ Suitable grape varieties for *Champaigne*: Chardonay and Pinot Noir
★ *Nira* is prepared from the Palmyrah juice
★ Wines prepared from berries like strawberry, blackberry and elderberry are known as berry wines
★ Famous fortified wine in Hungary: *Tokay*
★ Syphoning off the fermented wine to separate it from the solid deposits is known as "raking"

17. Processing of tomato:

★ Tomato sauce and apple sauce are quite popular in India
★ Solan Gola, Yashwant, Rupali and MTH-6 are most preferred tomato cultivars in for juice making
★ Winter tomatoes are superior quality because of more total solids
★ Lycopene is the self oxidizing isomer of carotene
★ Lycopene turns brown when it comes in contact with iron
★ Iron also forms black compounds with tannin when tomato and spices used

FPO specification for tomato processed products

Tomato product	*TSS*	*Other specifications*
Tomato juice	*5*	Sugar 1%, salt 0.5%, citric acid 0.4%
Tomato soup	*7*	
Tomato puree		Tomato pulp without skin or seeds
Medium tomato puree	*9*	Benzoic acid @ 250 ppm
Heavy tomato puree	*12*	Benzoic acid @ 250 ppm
Tomato paste	*25*	Made from strained tomato juice or pulp, benzoic acid @ 250 ppm
Concentrated tomato paste	*33*	
Tomato sauce/ketchup	*25*	Tomato solids 12%, 1% acetic acid, benzoic acid @ 750 ppm

★ Generally sugar content of tomato ketchup/sauces:10-26%
★ Salt content of tomato ketchup/sauces: 1.3-3.4%
★ Tomato sauce/ketchup contains 1.25-1.5% acetic acid
★ Pasteurization temperature for tomato sauce/ketchup is 85-90°C for 30min.
★ Tomato ketchup should be filled @ 88°C

★ Heating of tomato juice @ 82 to 88°C for 1 min.
★ Sterilization tomato soup @ 115°C for 40-45 min.
★ Tomato juice/pulp is extracted by hot pulping (superior quality) and cold pulping
★ Sauces are generally thinner and contain more total solids (minimum 30%) than ketch up (minimum 28%)
★ Minimum total soluble solids of sauces (other than tomato) should be 15% and acetic acid 1.2%
★ Colour of the sauce should be light
★ Formation of black ring in the neck of bottles is known as black neck
★ End point of cooking puree and paste determined by refractometer

18. Major products:

★ **Sauerkraut** meaning acid cabbage
  ✦ Fermented product (2-3% salt), lactic acid (1.5%)
  ✦ Suitable cabbage type: White cabbage
  ✦ Stimulate laxative property due to acetylcholine and lactylcholine (Ester)
  ✦ Common bacteria: *Leuconostoc mesenteroides*
  ✦ Ideal temperature for fermentation: 18-22°C (Rapid fermentation)
★ Mango slices (Amchur): Suitable stage for amchur product: Green, mature
★ Mango leather synonym to mango slab, amawat, ampaper
★ Suitable stage for mango leather: Ripe and juicy fruits
★ Fruit cheese: Guava, apple, pear and plum: Suitable stage for fruit cheese: Firm and ripe fruits
★ Fruit butter: Apple, peach, plum (Suitable stage: Firm and ripe)
★ Fruit toffee: Mango, guava, papaya (Suitable stage: Firm and ripe)

19. Papain:

★ Prepared from dried latex of unripe papaya fruit
★ Suitable drying temperature: 50-55°C
★ Dried papain moisture content: 5%
★ Most suitable preservative: SO_2 @1000 ppm

20. Points to ponder:

★ Tendrometer: Measuring tenderness of garden peas
★ Succulometer: Measuring a maturity of sweet corn
★ Brine floatation technique: Garden Pea
★ Fibre content: Asparagus

★ "Minimally processed" terms used to refer to as "lightly processed," "partially processed," "fresh processed," and "pre-prepared"

★ Minimally processed vegetables include peeled and sliced potatoes, shredded lettuce and cabbage, washed and trimmed spinach, chilled melon and other vegetable snacks, such as carrot and celery sticks and cauliflower and broccoli florets

★ The modified atmospheres that best maintain the quality and storage life of minimally processed products have an oxygen range of 2 to 8 percent and carbon dioxide concentrations of 5 to 15 percent

★ National Association of Fresh Produce Processors (NAFPP)

★ Potato is semi-perishable in nature because it contains 80% water

21. Food Spoilage

Useful bacteria:

1. **Vinegar bacteria**: *Acetobacter sp.*
   - ★ Aerobic bacteria
   - ★ Important species: *Acetobacter aceti, Acetobacter orleansis, Acetobacter schzenbachi*
2. **Lactic acid bacteria**: *Lactobacillus sp.*
   - ★ Facultative thermophiles
   - ★ Used in lactic acid production (Cheese and dairy products)
   - ★ *Lactobacillus plantarum*: Used for pickles preparation

Yeast:

- ★ Unicellular fungi
- ★ Prefer low concentration of sugar for growth
- ★ Commonly used for wine and beer production

Moulds:

- ★ Multicellular, filamentous fungi
- ★ Sensitive to heat

Important moulds:

- ★ Blue moulds: *Penicillium*
- ★ Black moulds: *Aspergillus*
- ★ Grey moulds: *Mucor sp.*
- ★ Spoilage of canned fruits: *Byssochlamys fulva*

Microbes	Minimum water activity (a$_w$)
Bacteria	0.91
Yeast	0.88
Moulds	0.80

★ Microbes require atleast 13% free water in foods for their growth

Type of spoilage in fruits and vegetables:

- ★ Grey mould rot: *Botrytis cinerea*
- ★ Rhizopus soft rot: *Rhizopus nigricans*
- ★ Blue mould rot: *Penicillium italicum*
- ★ Black mould rot: *Aspergillus niger*
- ★ Slimings or soury: Saprophytic bacteria

Spoilage due to mechanical damage:

- ✦ Mango: Stem end rot
- ✦ Banana: Crown rot
- ✦ Citrus: Green mould
- ✦ Apple: Blue mould
- ✦ Pineapple: Pedicel rot

★ Acetic acid fermentation: Production of vinegar from fruit juices

★ Lactic acid fermentation: Salt and acid tolerant bacteria
- ✦ Anaerobic bacteria
- ✦ Intra-molecular oxidation-reduction process
- ✦ Cabbage: *Leuconstoc mesenteroides*: Sauerkraut
- ✦ Cucumber: *Leuconstoc mesenteroides*: Pickles
- ✦ Lactic acid bacteria most active at 30°C

★ Alcoholic fermentation: e.g. Cider
- ✦ Carbhohydrate converted into alcohol by fermentation (Anaerobic process)
- ✦ Main yeast: *Saccharomyces cerevisiae*

Browning reactions:

★ Browning reactions due to enzymatic and non enzymatic

Enzymatic browning: Apple, bananas, brinjal
- ✦ Brown colour due enzymes: Polyphenol oxidase

Non-enzymatic browning:

★ Sugar and sugar related

- Maillard browning: e.g. Roasted coffee beans
- Caramelization: Due to high temperature

★ 1g CHO: 4K Calories
★ 1g fat and oil: 9K calories
★ 1g protein: 4K calories

Natural toxins:

★ Potato: Protease inhibitors
★ Saponins: Spinach and asparagus
★ Goitrogens: Cabbage
★ Oxalic acid: Rhubarb, spinach, beet

Statutory provisions for quality control in India:

★ Prevention of Food Adulteration (PFA) Act: 1954
★ Fruits Product Order (FPO): 1955
★ AGMARK: Agricultural Produce (Grading and Marketing) Act: 1937
★ Central Agmark laboratory is located at Nagpur, Maharashtra
★ Export (Quality Control and Inspection) Act: 1963
★ Export (Quality Control and Inspection) Rules: 1964
★ The Consumer Protection Act: 1986
★ Food Safety and Quality Control Act: 2001
★ Food Safety and Standardisation Authority (FSSAI) Act: 2005

Central Food Laboratories:

★ Central Food Laboratory (CFL), Kolkata, West Bengal
★ Food Research and Standardization Laboratory (FRSL), Ghaziabad, Uttar Pradesh
★ Public Health Laboratory (PHL), Pune
★ Central Food Technological Research Institute (CFTRI), Mysore, Karnataka
★ Defence Food Research Laboratory (DFRL), Mysore, Karnataka
★ Central Institute of Post Harvest Engineering Technology (CIPHET), Ludhiana, Punjab
★ National Institute of Food Technology Entrepreneurship and Management (NIFTEM), Kundli, Haryana
★ Indian Institute of Crop Processing Technology (IICPT), Thanjavur, Tamil Nadu
★ National Agricultural Cooperative Marketing Federation of India Ltd. (NAFED), New Delhi

3-104, 208-233, 343-379,
422 - 450,
471 - 475,
508 - 529 - MAP
530 - 564 - PHT.

BASICS Horticulture

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